VOL. XXXVIII. No. 1 JANUARY, 1960

THE STRUCTURAL ENGINEER

THE JOURNAL OF THE
INSTITUTION OF STRUCTURAL ENGINEERS

The Design and Construction of the New Assembly Building for the Ford Motor Company Limited, Dagenham

by D. Lax (Member) and F. T. Bunclark (Member)

Lightweight Fire Protection and the Structural Engineer

by A. R. Mackay (Associate-Member)

The Structural Engineer in the Field of Atomic Energy

by T. C. Waters (Delegate Member of Council)

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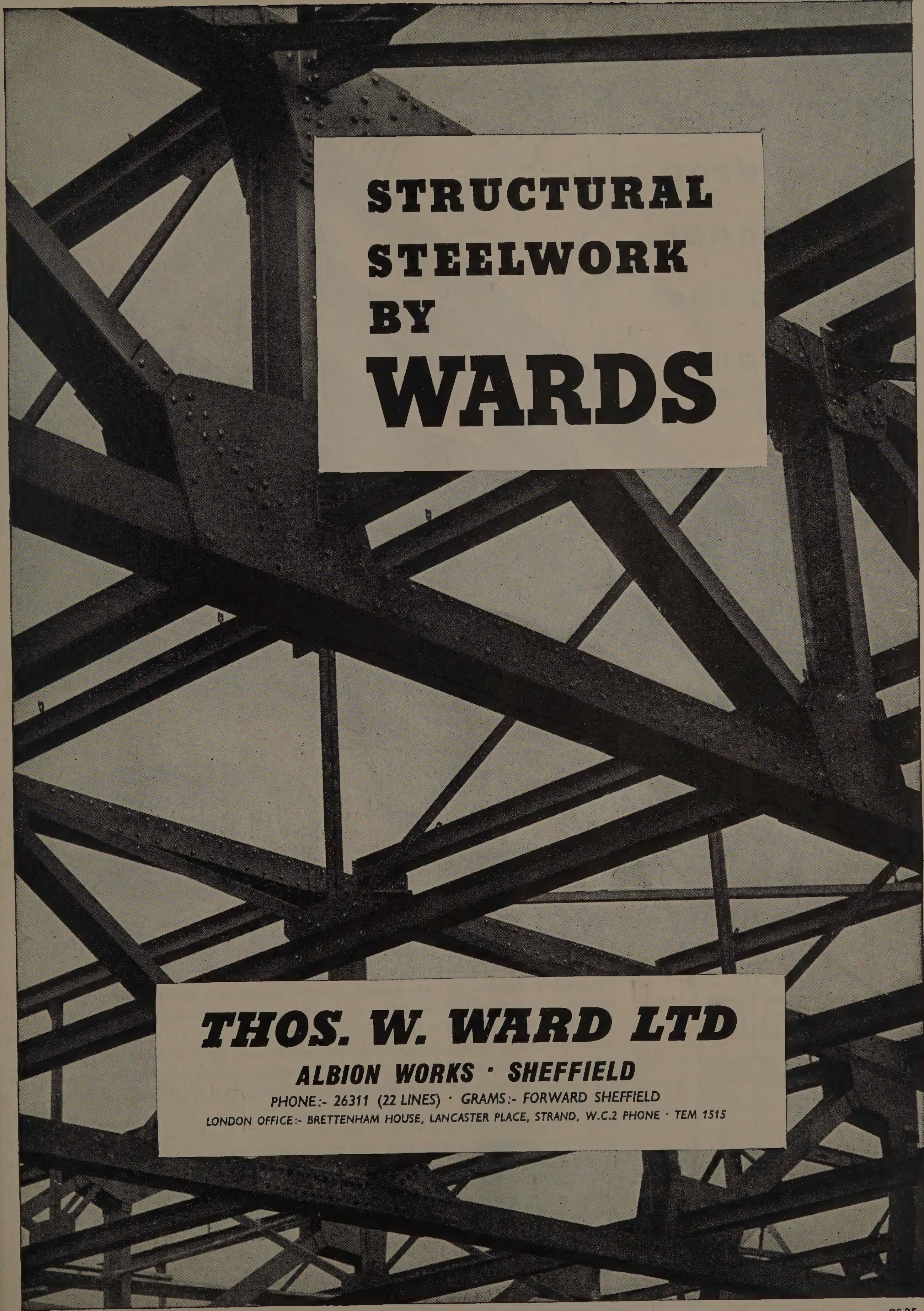
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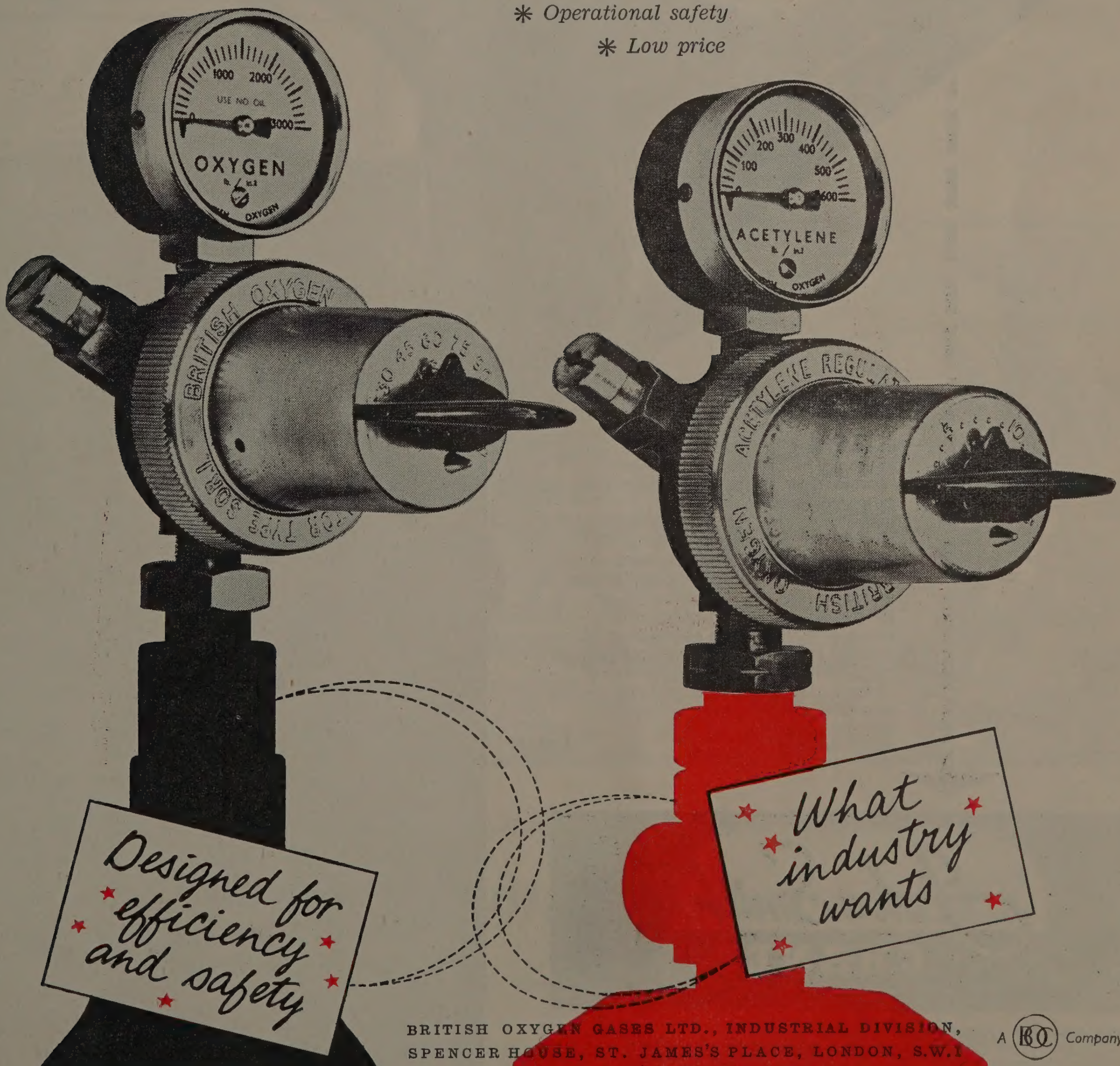

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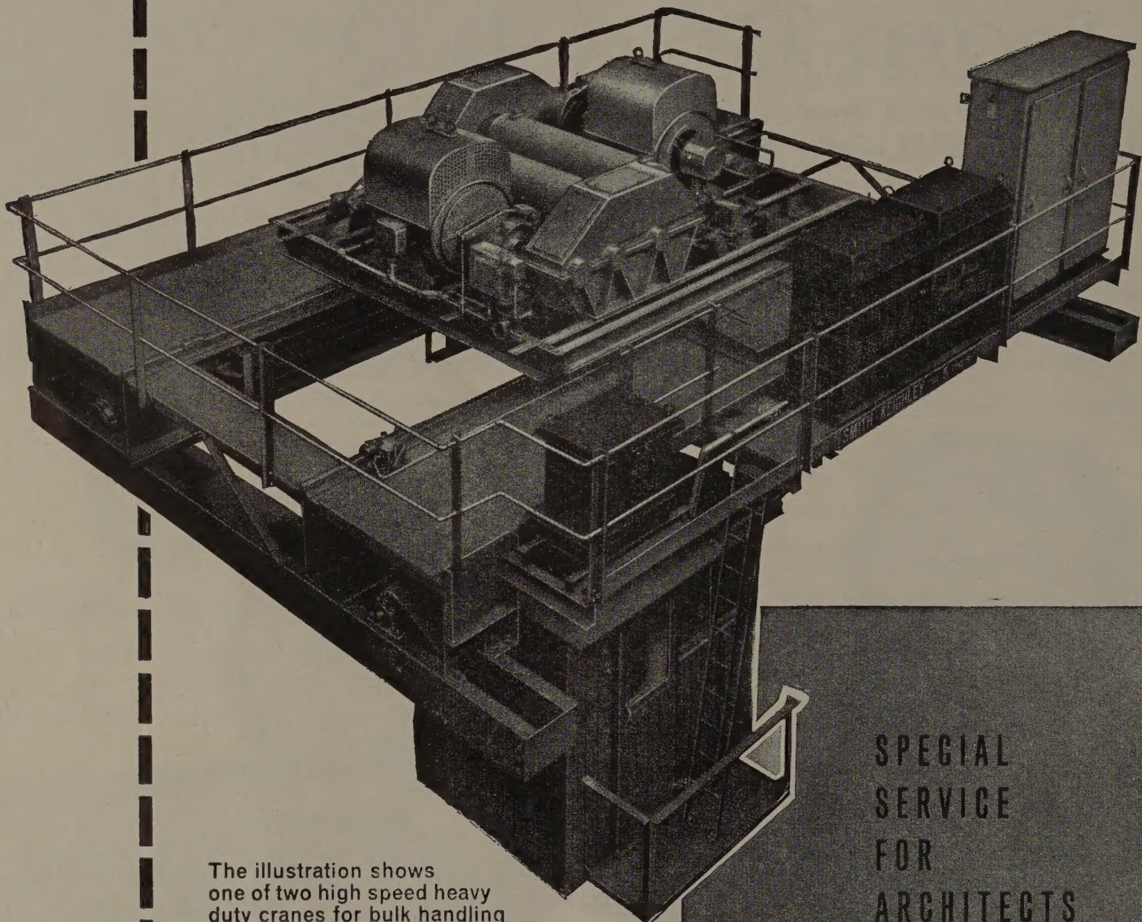

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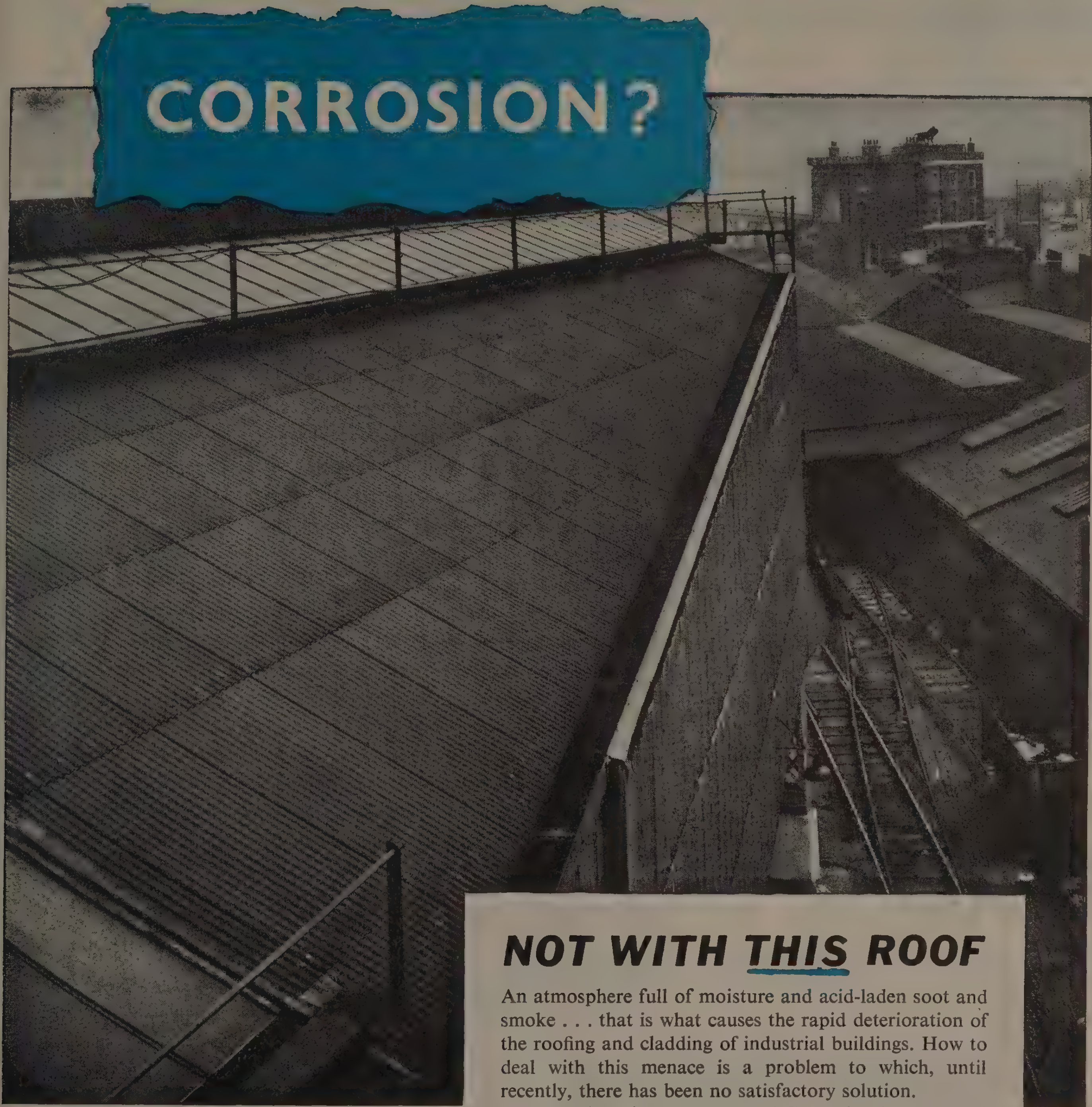

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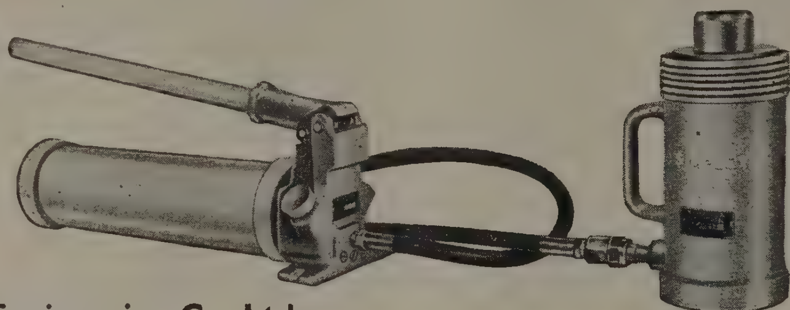

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$2\frac{3}{8} \times 2\frac{3}{8}$	$1\frac{7}{8} \times {}^{13}/_{16}$
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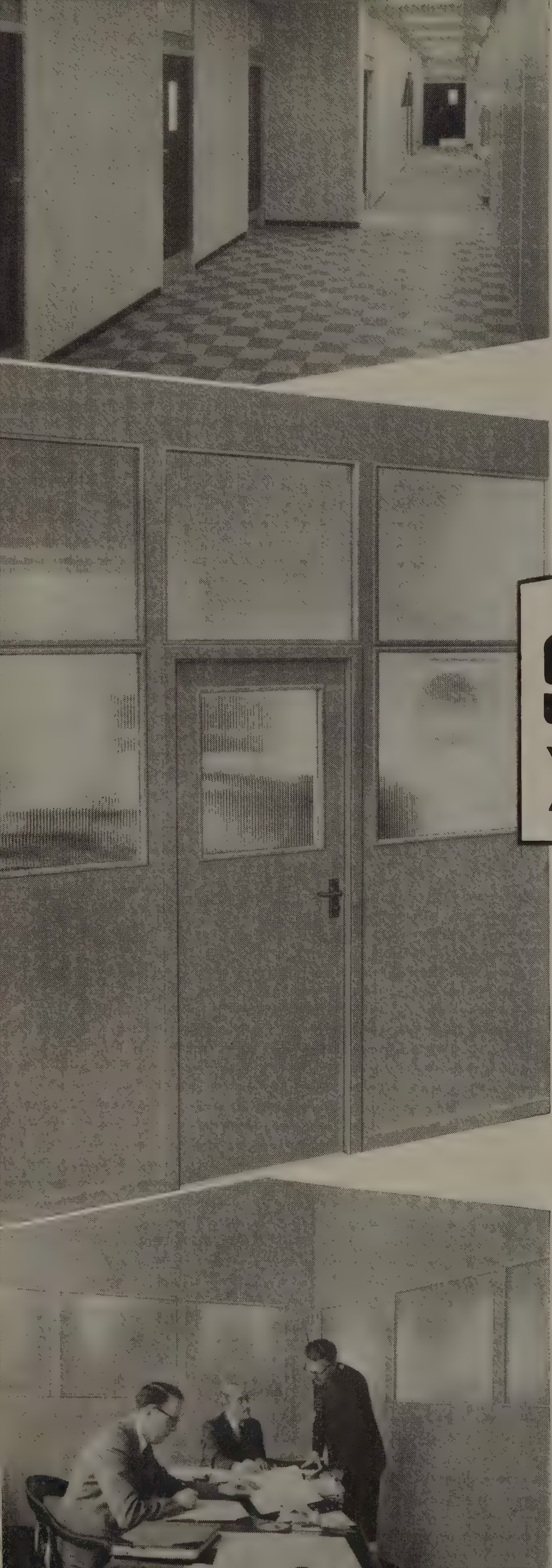

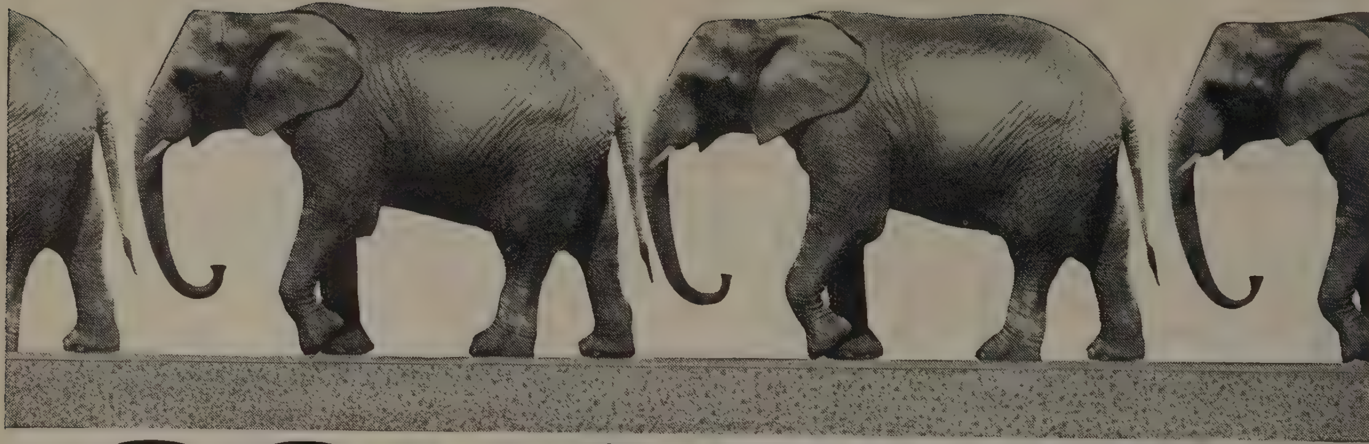

VOL. XXXVIII. No. 1. JANUARY, 1960

THE STRUCTURAL ENGINEER

THE JOURNAL OF THE INSTITUTION OF STRUCTURAL ENGINEERS

Founded 1908. *Incorporated by Royal Charter* 1934.

11 UPPER BELGRAVE STREET, LONDON, S.W.1. Sloane 7128/9.

CONTENTS

All Editorial communications should be addressed to The Editor, The Structural Engineer, 11, Upper Belgrave Street, S.W.1. All MSS. should be typewritten and algebraic signs and formulae be indicated distinctly.

The Institution of Structural Engineers, whilst being at all times desirous of receiving communications from members and others, does not accept any responsibility for the opinions expressed by any individual Authors or Speakers.

Annual Subscription Rate to the Journal £3 3s. 0d. post free.

Printed and Published for the Institution by JOHN MORRIS PUBLICITY LTD., Publicity House, 41 Streatham Hill, London, S.W.2, to whom all communications regarding advertisements should be addressed.

The Design and Construction of the new Assembly Building for the Ford Motor Company Limited Dagenham*

by D. Lax, M.I.Struct.E.,

Chief Engineer, Posford, Pavry & Partners, Consulting Engineers

and

F. T. Bunclark, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E.,

Chief Engineer, G. Percy Trentham Limited, Contractors

Synopsis

A descriptive paper dealing with the design and construction of the building enclosing the new vehicle body finishing and final assembly plant at Dagenham, Essex.

General

With the developments in motor vehicle manufacture since the 1939/45 war, the whole of the conception of the assembly of the vehicle has changed. Instead of a chassis in which the mechanical parts are housed and on which a body is placed, the body now assumes prime importance by also forming the chassis and thus becomes the basic part of a final assembly line.

When The Ford Motor Company decided in 1954 to carry out a major expansion policy, the largest single item was the lay-out, design and construction of an entirely new paint, trim and final assembly building.

The task which confronted the planning staff of The Ford Motor Company before any firm scheme for this building could be formulated was enormous, bearing in mind the diversity of the various products and processes which must be brought together to form one vehicle. Considerable use was made of the experience gained by The Ford Company of America in their post-war expansion programme.

This planning has now reached maturity in the paint, trim and final assembly building constructed at Dagenham, Essex on the 48 acre site of The Ford Sports Field, which is on the east side of the existing body manufacture plant in Kent Avenue, the site plan of which is shown in Fig. 1.

The building is basically of two-storey construction with large areas of plant houses at the normal roof level of the upper floor.

Including the facilities block and the receiving bay, the ground floor size is 1215 ft. long in an east/west direction and 630 ft. wide in a north/south direction. This floor forms the final assembly section, including the body upholstery and fitting known as body trim.

* *Paper to be read before the Institution of Structural Engineers at* 11, *Upper Belgrave Street, London, S.W.*1, *on Thursday,* 14*th January* 1960, *at* 6 *p.m.*

The first floor is 1080 ft. long by 405 ft. wide and contains the phosphating plant and rinse, the new paint shop, the wet sand decks and the drying ovens. Vehicle bodies are automatically lowered to the trim and final lines through large apertures left in the floor on the south side.

The first floor is linked by means of a large conveyor bridge to the existing " body-in-white " section situated on the west side of Kent Avenue where vehicle bodies are prepared up to the finished steel unpainted, untrimmed stage.

On the north side of the building is a facilities block which provides accommodation for the administration staff, the main canteens and kitchens, together with the medical centre, which, in conjunction with those already provided in the existing main plant and body manufacture plant provides a comprehensive medical service for all personnel, including fully equipped X-ray facilities and a physiotherapy department.

The receiving bay situated on the ground floor in the south bay of the main building takes all incoming material used in the production lines other than the vehicle bodies.

On the low level roof which is formed between the plan area of the first floor proper and the ground floor are built the fan houses for the ventilation plant for the ground floor, four sub-stations for electric supply distribution and four buffets which supplement the main canteens in the facilities block.

The main toilet blocks and locker rooms for the works personnel are suspended between the first and ground floor levels in the form of mezzanines, generally with access to both levels.

The air conditioning plant for the paint spray booths and for the normal ventilation of the first floor is contained in the main plant houses constructed on the higher roof level and special weathered access through this roof is also provided for the 248 chimneys and apertures required for the general air intake and the exhaust ducts from the drying areas.

The principal access for works personnel into the main assembly building is through three tunnels constructed under the facilities block and the first two bays of the ground floor assembly.

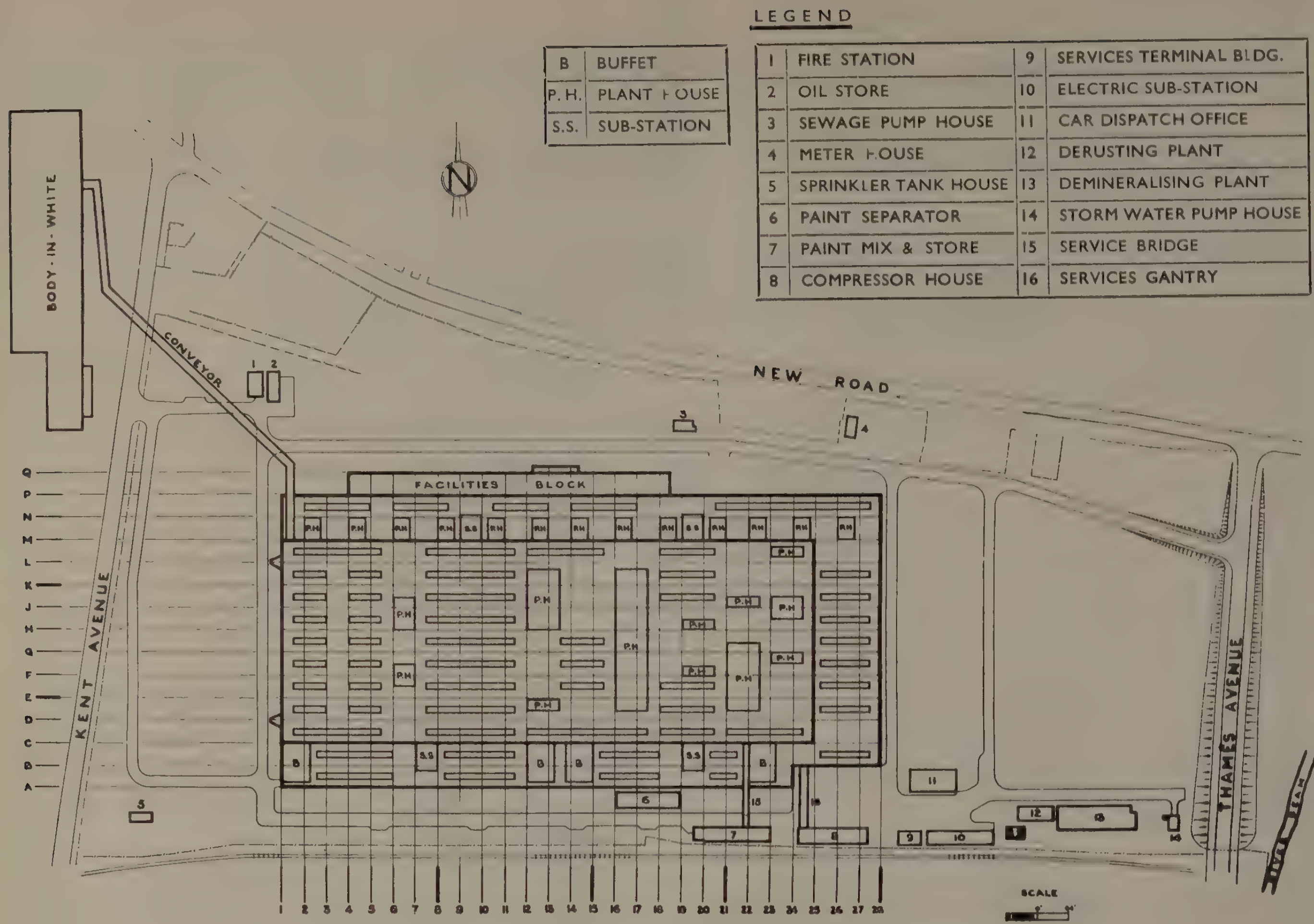

Fig. 1

Fig. 2.—Aerial view from the north-west showing extent of conveyor bridge and location of Body-in-White Section.

Fig. 3.—Aerial view from the east. The extent of the plant houses and ventilation ducts on each roof level is clearly shown.

The ancillary buildings, which house plant or services which form a vital part of the overall production, are sited on the north and south sides of the main building, the major ones being :—

The paint separator.
Paint mix and store.
Compressor house.
Services terminal building.
Demineralising plant.
Car despatch office.
Fire station.
Oil store and pump house.
Storm water pump house.
Sewage pump house.

Each of these buildings is an independent structure in itself and will be briefly described later.

To the east of the main building are the parking areas to receive cars awaiting delivery. Figs. 2, 3 and 4 show aerial views of the project.

Site and Soil Exploration

The normal site level in relation to the Ordinance Datum is about zero and is subjected to flooding from the nearby River Beam on certain conditions of the tide.

The strata underlying the site is similar to that existing for large areas adjoining the north bank of the River Thames. On the surface is a layer of brown clay between three and six feet thick, under which is a strata of peat varying in depth between 13 and 16 ft. Beneath this are mixed stratas of grey clay, sand and ballast of various sizes with occasionally lenses of green sand, and generally the whole overlying a thick strata of fine grey sandy clay.

The general standing water level over this area is approximately 12 ft. from normal ground level and does not appear to be influenced by tidal variation.

A series of test piles were driven in conjunction with a limited boring investigation ; the limitation being due to the speed at which the information was required to initiate the main site work.

The plan position of the bores and the test piles used for determination of drive are shown in Fig. 5 and the typical driving results from a two ton hammer dropping four feet plotted for penetration per ten blows together with interpolated cross sections of strata obtained from the adjacent bores are shown in Fig. 6. It will be seen that where the lenses of green sand occur, the driving in the upper layers is easier until these are penetrated. There was a tendency for piles to pull up at or about 27 ft. from the normal ground level under varying conditions of set. Upon driving through this range the driving eased in all cases until depths of the order of 44 ft. were attained.

Loading tests were carried out on certain of the piles which had been driven to a minimum set of 2 in. for ten blows, with a two ton hammer dropping through 4 ft. with three consecutive sets. The test load was 90 tons.

The results were consistent, the maximum initial settlement being $\frac{3}{16}$ in. which was held for three days. Upon unloading the recovery was $\frac{1}{8}$ in., giving a permanent compression of $\frac{1}{16}$ in.

Generally 14 in. $\times$ 14 in. precast concrete piles of pre-stressed type have been used to a maximum working load of 50 tons each, and under certain conditions a number of proprietary driven and pressure piles were used.

Site Levelling and Drainage

Due to the very low level of the site all surface water and sewage had to be elevated by pumping to ensure freedom from flooding. To lessen the risk of surface water flooding the site, it was agreed to place four feet of filling material over the whole area. Due to the acid

Fig. 4.—Aerial view from the south-west. This shows the extent of the site.

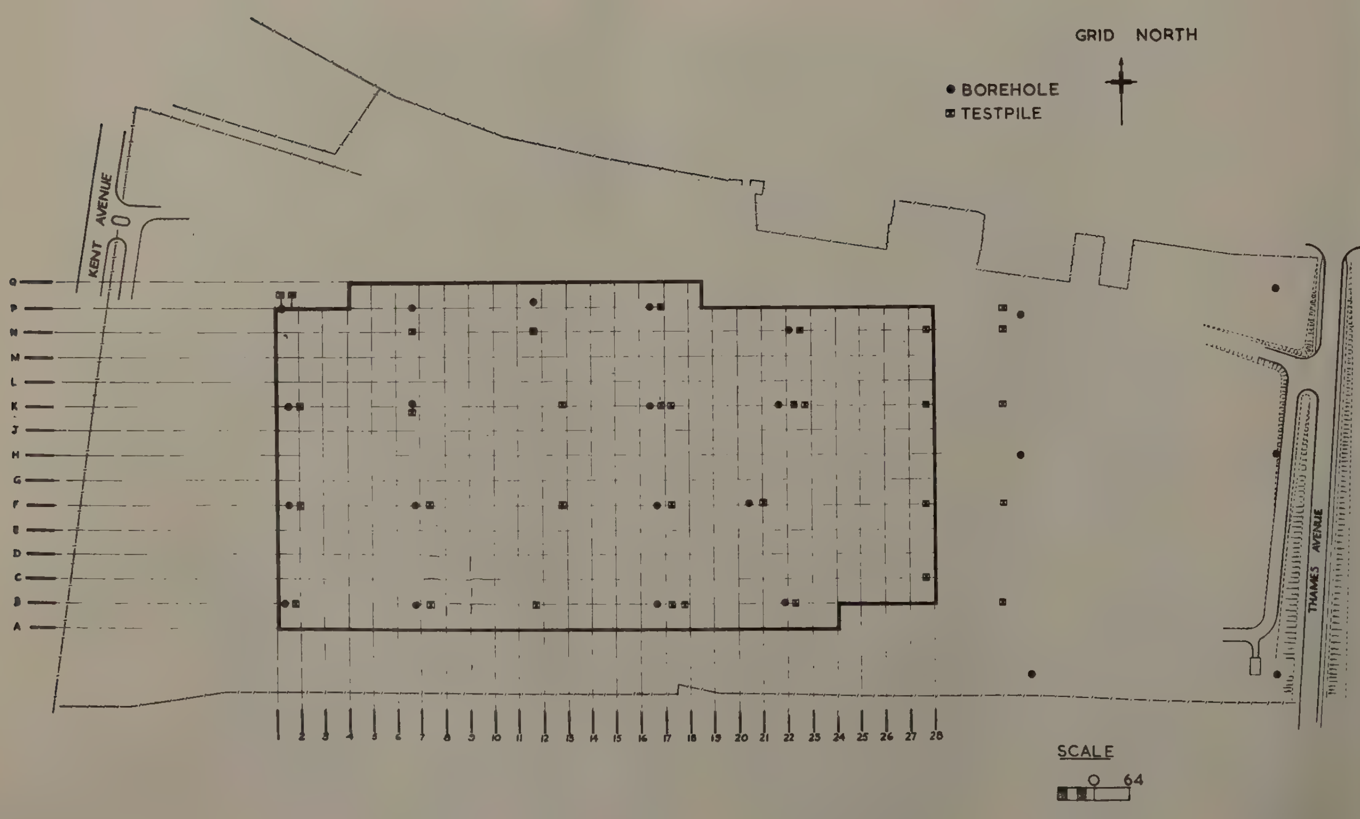

Fig. 5.

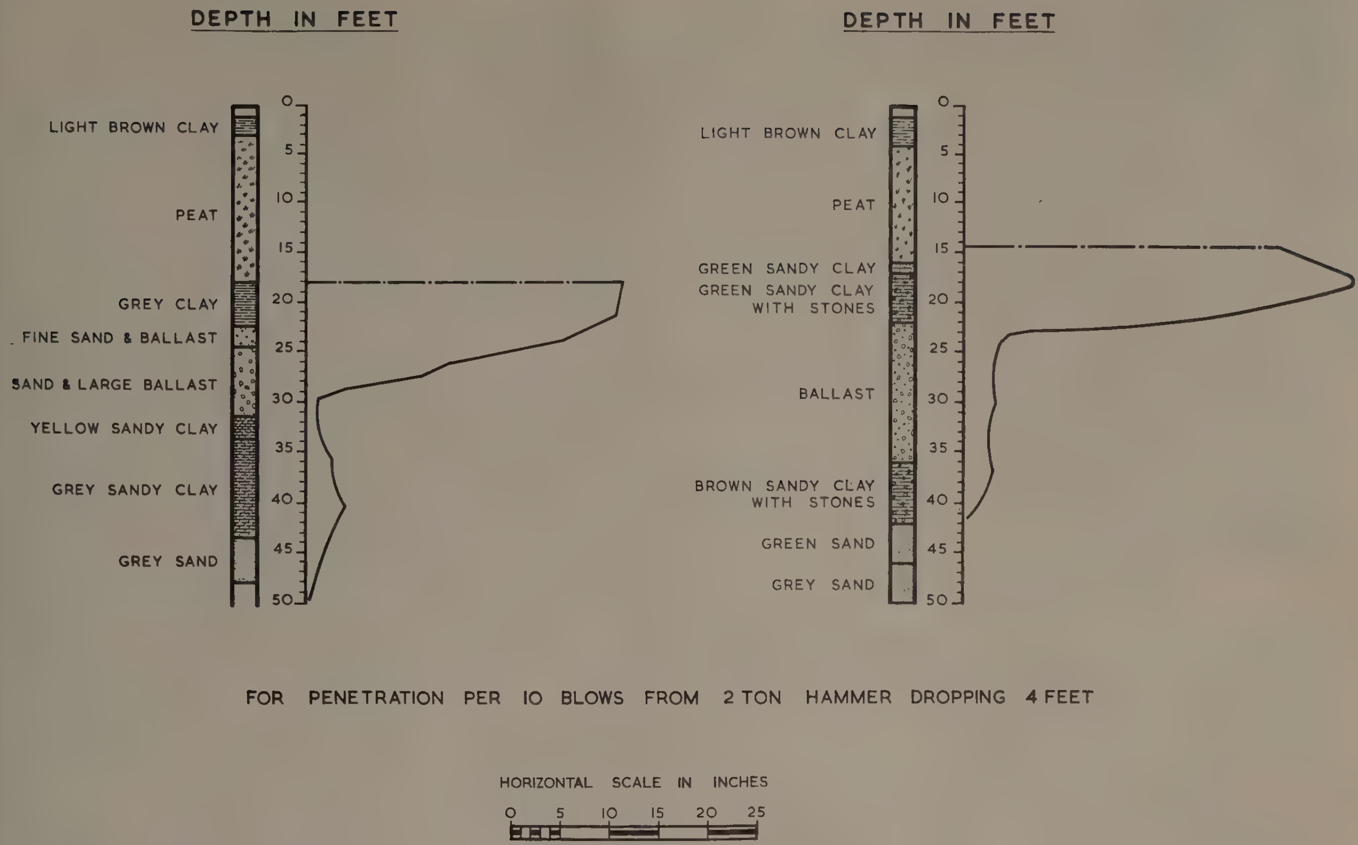
DEPTH IN FEET
LIGHT BROWN CLAY
PEAT
GREY CLAY
FINE SAND & BALLAST
SAND & LARGE BALLAST
YELLOW SANDY CLAY
GREY SANDY CLAY
GREY SAND
DEPTH IN FEET
LIGHT BROWN CLAY
PEAT
GREEN SANDY CLAY
GREEN SANDY CLAY WITH STONES
BALLAST
BROWN SANDY CLAY WITH STONES
GREEN SAND
GREY SAND
0 5 10 15 20 25 30 35 40 45 50
FOR PENETRATION PER 10 BLOWS FROM 2 TON HAMMER DROPPING 4 FEET
HORIZONTAL SCALE IN INCHES
0 5 10 15 20 25

Fig. 6.

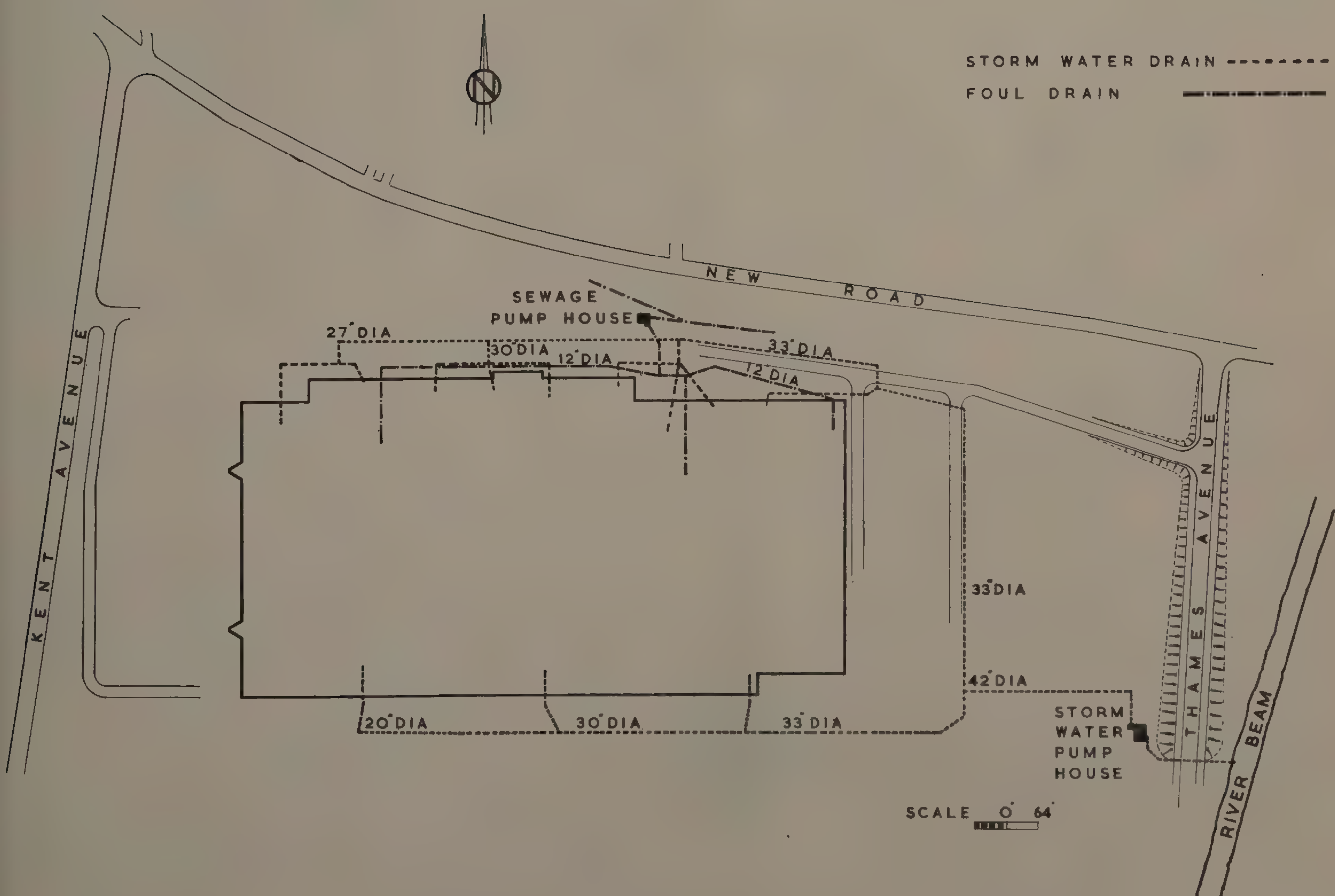
STORM WATER DRAIN
FOUL DRAIN
NEW ROAD
KENT AVENUE
THAMES AVENUE
RIVER BEAM
SEWAGE PUMP HOUSE
STORM WATER PUMP HOUSE
27" DIA
30" DIA
12" DIA
33" DIA
12" DIA
33" DIA
42" DIA
20" DIA
30" DIA
33" DIA
SCALE 0' 64'

Fig. 7.

condition of this filling material sulphate resisting cement was used for all below ground in situ concrete work.

The general lay-out of the surface water drainage from the site is shown in Fig. 7. Inside the main building the surface water is carried to the side walls by overhead collector mains, a practice which has been found satisfactory on other buildings of this type, and thence by underground pipes to the special pumping station constructed at the south-east corner of the site where it is elevated into the River Beam by pumps capable of handling 10,000 gallons of water per minute.

The foul sewage is taken down the stanchions from the elevated toilet blocks, special provision being made in the stanchion bases where necessary, and thence by collector pipes encased and suspended underneath the ground floor structural slab to the main sewage pump house situated on the north side of the site where it is elevated by pumping into the Dagenham Council main sewer in New Road.

Ground Floor Construction

The module of construction was specified by The Ford Motor Company at 45 ft. in both north/south and east/west directions to meet the planning requirements for their plant. The whole building was planned about this grid, the location and identification of which is shown in Fig. 1.

The superimposed loading on the ground floor was assessed at 3 cwt. per sq. ft. generally, with up to 5 cwt. per sq. ft. on special areas of limited extent.

The main building stanchions are placed at the intersection of the grid, and have accrued loading from the superstructure of up to 600 tons, which together with the ground floor loading require up to 14 piles.

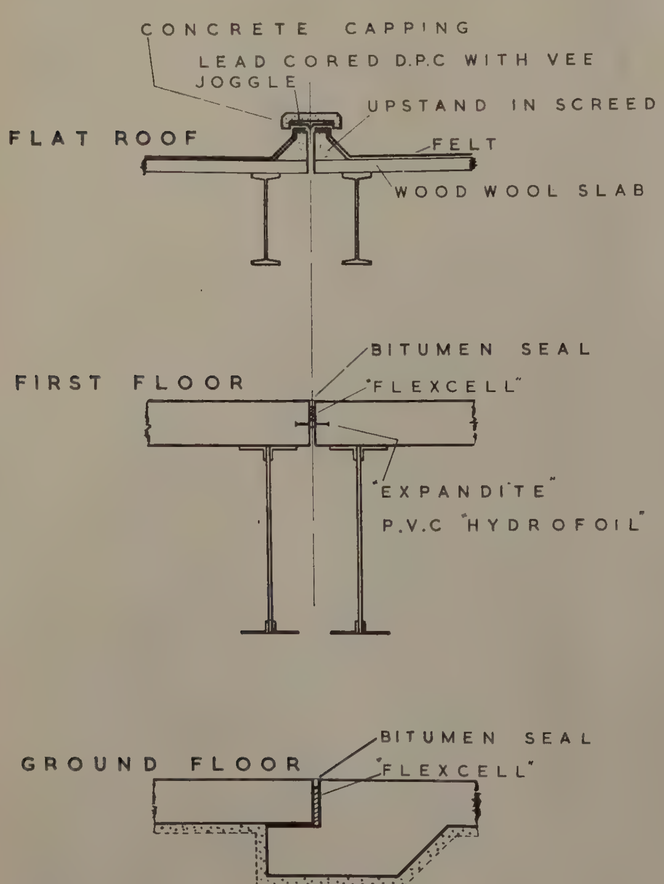

Fig. 8

To enable the general contractor to proceed with the main piling in advance of firm information regarding the loading from the superstructure especially from the first floor and the plant houses, it was necessary to finalise the ground floor slab piles on a 15 ft. square module and drive a nominal group of piles for the stanchions which could be added to later generally in the form of raker piles to keep the pile caps as small as possible. A minimum pile spacing of 4 ft. 6 in. was used when driven vertically, and all raker piles were driven to give this minimum at the toe.

The stanchion pile caps were depressed so that the structural ground floor slab could be laid on top later.

A bituminous layer was incorporated between the structural slab and the pile cap. The shaft of the stanchions was isolated from the slab by a $\frac{1}{2}$ in. thick layer of a flexible jointing material so forming a pocket for the stanchion base. By this arrangement the construction of the slab could proceed independently of the steelwork.

The size of this building called for special consideration to be given to expansion and the position of expansion joints. These were provided on lines E and K in the east/west direction and on lines 8 : 15 : 21 : 28 in the north/south direction, the line 28 being for future extension. Except for the pile cap the building was separated for the whole height of the construction. Fig. 8 shows the type of expansion joint adopted for each level through the building.

The normal ground floor structural slab is 10 in. thick reinforced with $\frac{5}{8}$ in. diameter high tensile steel bars at 15 in. centres both ways top and bottom, all bars being in straight lengths. The general form was of flat slab construction supported on single mushroom headed piles at 15 ft. centres both ways, the drop section of the mushroom being 18 in. deep below the underside of the slab and splayed at 60° to the horizontal from the outside of the pile. Additional $\frac{1}{2}$ in. diameter high tensile steel at 15 in. centres is provided in both directions in the top of the slab over the piles.

The construction programme called for an area of floor 585 ft. long by 45 ft. wide to be constructed each week for a period of six months.

The need to reduce the number of construction joints and simplify the form of construction led to the use of road laying techniques for the main floor slab. Bays up to 225 ft. long, between the main expansion joints, with construction joints to adjoining 15 ft. bays north/south across the site were used, the construction joint being central between the piles.

Shrinkage cracking occurred to a limited extent in the initial pours at or about 20 ft. centres. To reduce these a resin based curing membrane was sprayed on the top of the concrete immediately after placing; this gave excellent results and no further case of shrinkage cracking was observed.

The final lay-out and position of the general plant on the ground floor was not known at the time of laying the structural slab. To receive conduits and other services it was agreed to use a 3 in. thick screed over the whole floor area, and to ensure the best possible conditions for bond with the main slab the whole area was scarified before laying.

Superstructure

The headroom generally provided for the main production area of the ground floor is 18 ft. and for the first floor 19 ft., which in turn gives a ground/first finished floor height of 26 ft. and first to normal main roof height of 25 ft. 6 in.

Fig. 9 shows a part cross section through the building.

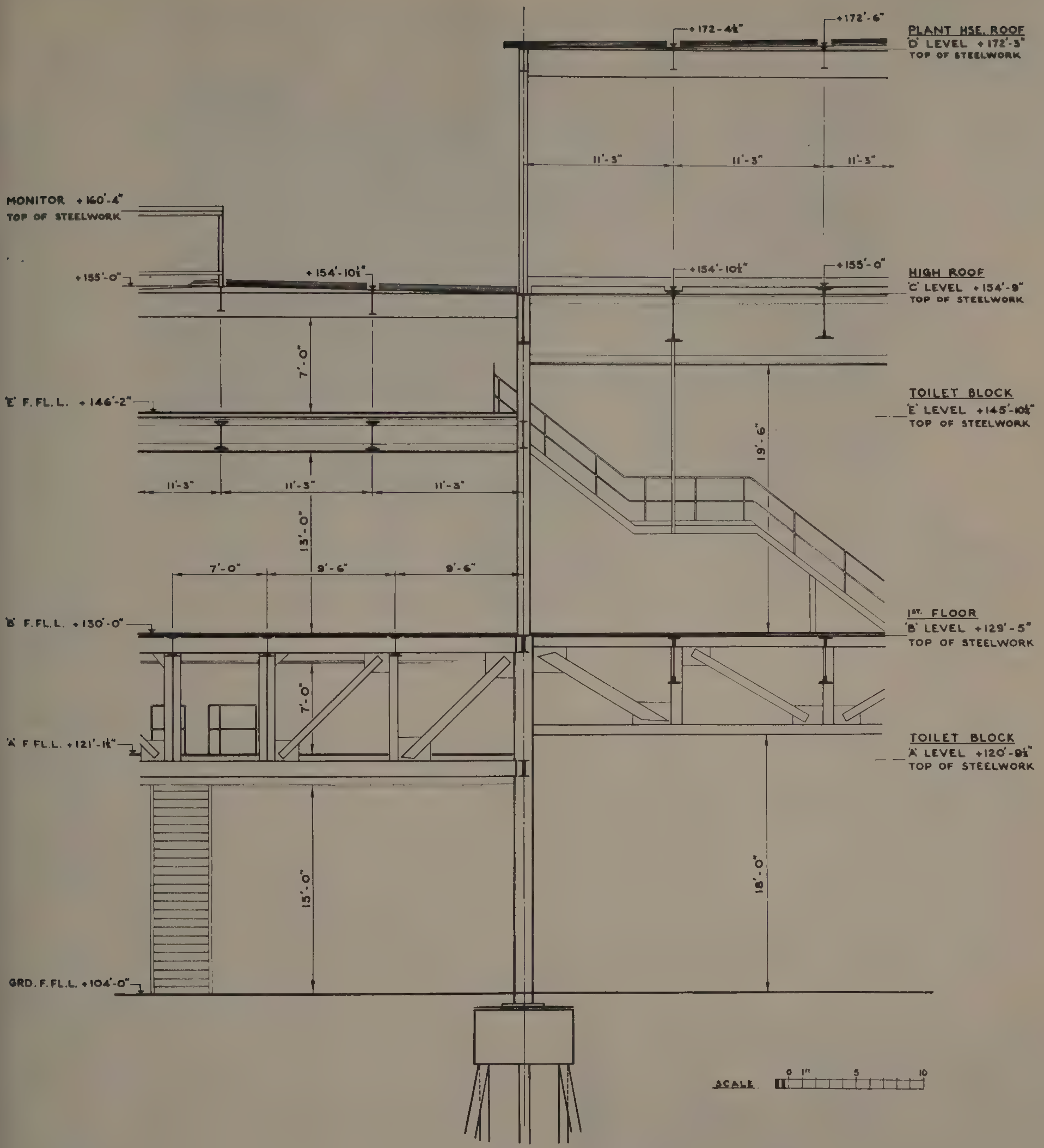

Fig. 9.

The first floor filler joist panels are designed for a general superimposed load of 300 lb/sq. ft. and are formed of 5 in. × 3 in. × 11 lb. steel filler joists at 2 ft. 6in. centres, with two inches of concrete over the top flange which has a monolithic topping of granolithic and reinforced with a 4.32 pounds per square yard steel mesh. The various stages of this construction are shown in Fig. 10.

Due to the large area of floor carried by the supporting steel, an easement to 200 lb/sq. ft. has been taken for the superimposed load for the main structural steel design.

For speed of erection and to keep the ground floor free from obstruction, preformed concrete infilling panels were laid in the root of the filler joists to form permanent shuttering to the soffit. The upper surface of these panels was roughened in casting to form a key with the in situ concrete.

Large areas of the first floor are occupied by the paint spray booths, wet sand decks and the enamel drying ovens. The treatment of the first floor under these areas may be of interest.

For the spray booths the surface of the concrete was first thoroughly cleaned and given a one-to-one coat of bitumen/water sealer well scrubbed in at 100 sq. ft. per gallon. This was followed by a scrim base coat of

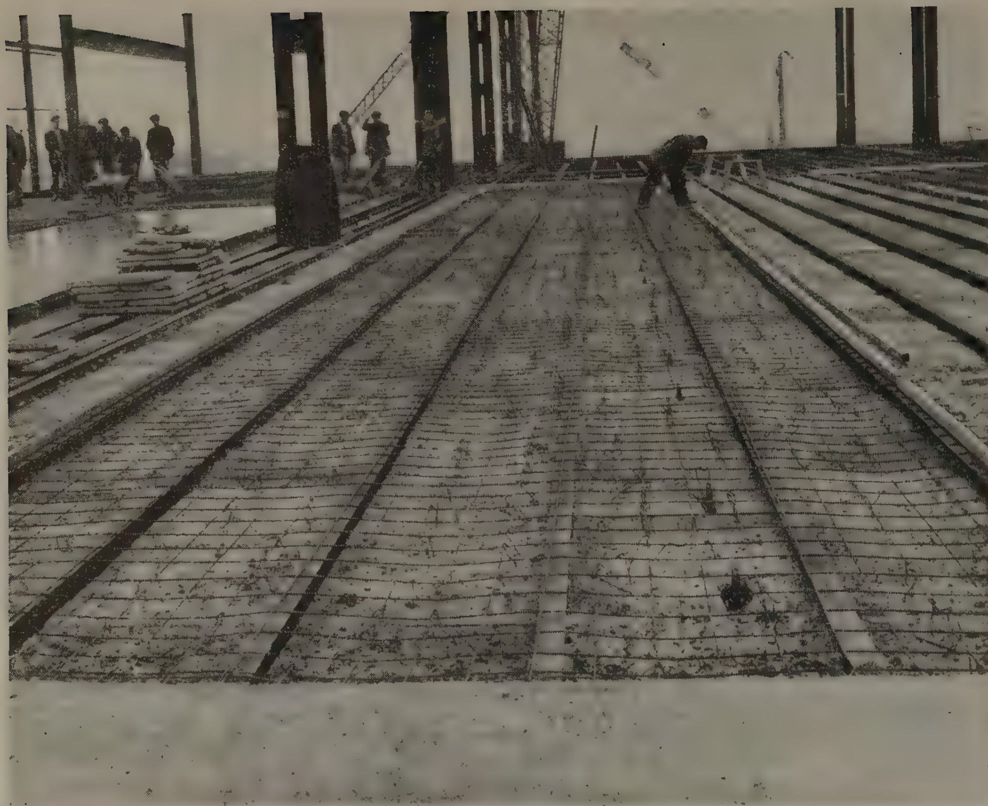

Fig. 10.

undiluted bitumen compound at the rate of one and a half gallons per 100 sq. ft. on which a rotproof cotton is embedded and followed by two further coats of bitumen compound.

A screed of 1 : 2 : 2 : 4 mix of cement/sand/bitumen compound/granite chippings $\frac{3}{4}$ in. to dust was laid to falls to a minimum total thickness of $1\frac{1}{2}$ in. in two layers with a bitumen sealing coat between. The bitumen compound used in this part of the work was a proprietary type.

The need for this rather rigid specification is due to the nature of the process.

For the wet sand decks and the body phosphating systems, asphalte tanking with a protective covering of concrete is used, on top of the normal structural floor.

The drying ovens are required to work at temperatures of 260° F. for steam and 400° F. for gas operation, and the floor under these ovens provided a special problem.

The surface was cleaned and one coat of a proprietary bituplastic compound was well brushed in, over which a fibreglass blanket 0.03 in. thick was laid followed by a further coat of bituplastic compound.

When the surface was dry, asbestos-cement sheets of the " super 6 " type were laid over the whole area, so that the ends butted tightly together and the corrugations were in line. This was achieved by laying lengths of steel tube of suitable size on the floor in the upstanding corrugation. These tubes were withdrawn later.

Over the asbestos cement sheets a 5-in. thick (minimum) concrete slab was cast reinforced with steel mesh No. 62 in the bottom and 65 in the top. Holding down bolts for plant were set in this slab where necessary.

Copper expansion joints were incorporated into the slab at 12 ft. centres and the joint gap above and below the copper filled with asbestos.

The main supporting structure is of steel and all parts of the main building and the major ancillary building are of framed construction.

The basic framing lay-out for the first floor and general roof level is shown in Fig. 11.

The roof units and the steel filler joists on the first floor span 11 ft. 3 in. between secondary beams spanning 45 ft. in a north/south direction, which in turn are carried on main steel spanning 45 ft. in an east/west direction. The tonnage of steel in the main building is approximately 16,000 tons which required to be erected in twelve months.

The supply, fabrication and erection of this quantity of steel into one building at a time when constructional steelwork was in some national demand necessitated a very flexible design to accept any type of fabrication, and to use as much capacity as could be made available. This called for careful planning so that a continuous run on any type of section could be avoided. Welded or riveted construction had to be freely interchangeable for either lattice or plate girder work.

It was found that double plated joist stanchions battened together were best suited to the building, the centres of joists being at 16 in.

The main steel for the first floor is double lattice girders at 16 in. centres, each carrying its appropriate area of floor laid independently.

The secondary beams on the first floor are plate girders of varying fabrication, but in no case were welded and riveted construction mixed in the same 45 ft. sq. module.

The normal main roof steel did not require double girders as the load carried did not overstress the economic section required for a reasonable span/deflexion ratio and were usually of single plate girder construction.

The secondary roof beams are generally of plated beam or plated girder construction, dependent upon the load applied.

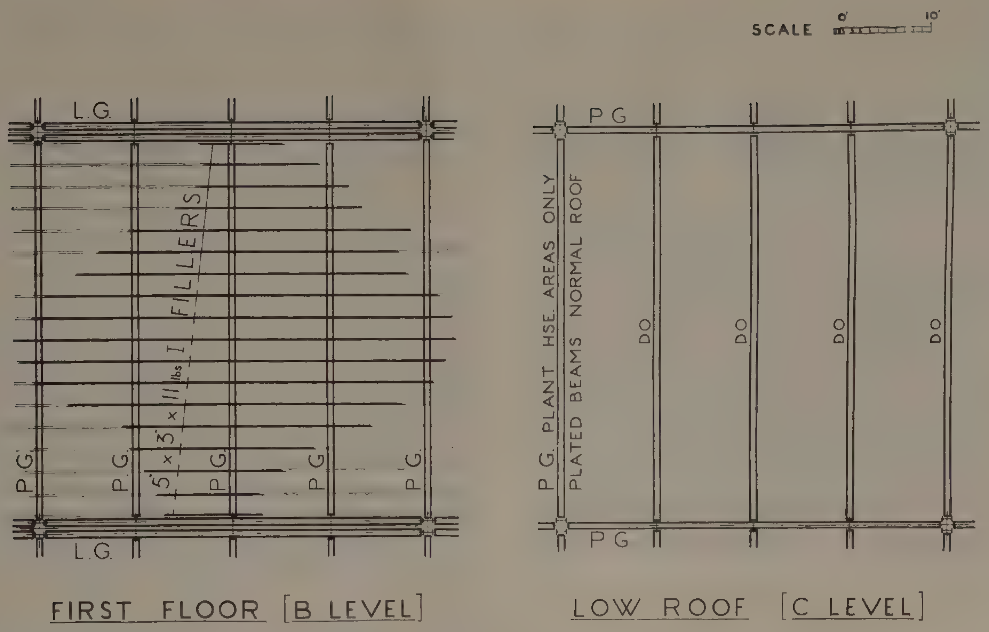

Fig. 11.

To eliminate excessive screeding on the roof units, the secondary steel in the centre of the 45 ft. module was raised 3 in., the steel at quarter points 1½ in. and on the grid, normal roof level for the steelwork, thus giving a fall to the roof units of 3 in. in 22 ft. 6 in.

The only drainage screeding necessary was that required to give cross falls into the drainage points.

The plant houses sited on the roof proper were steel framed and of similar building construction to the main ground and first floors.

The normal roof construction was of two types. Where access was restricted, wood-wool slabs in steel interlocking edge channels were used on spans of 11 ft. 3 in. Where access was required to the plant houses and for 15 ft. in from the side walls of the building, precast concrete unit construction was adopted, suitable for superimposed load of 100 lb/sq. ft., or a one ton wheel load in any position. The precast concrete units were screeded and then finished in mastic asphalte of suitable quality for occasional trucking.

A more detailed description of the wood-wool section of the roof may be of interest. This type of roof has only been developed for large roof areas in recent years, and to the best of the information available the roof at present required is the largest area laid in this material.

Fig. 12 shows the preliminary loading test on a section of roof developed and tested to the instructions of the consulting engineers.

Three-inch thick wood-wool slabs with 16 gauge galvanised steel interlocking edge channels were formed into panels 11 ft. 3 in. long by 2 ft. wide, the soffit of the wood-wool panel having a sheet of flexi-asbestos ⅛ in. thick laid in between the lower flanges of the channels and bonded to the wood-wool.

Fig. 13 shows the erection of the panels.

After placing these panels closely side by side a layer of 19 gauge 2 in. mesh galvanised wire with 6 in. laps at the joints was stapled down to the wood-wool slab and the whole covered with a ½ in. minimum thickness of 1 : 4 cement/sand mortar, dependent upon the cross falls to the drainage points.

Three layer felt roofing was then placed over the whole area, the lower layer of which was fully bonded to the mortar screed.

The toilet blocks, suspended on mezzanines, are steel framed with concrete floors and with walls of gypsum plaster on patent expanded metal lathing.

Fig. 14 shows the basic plan adopted for the suspended toilets and locker rooms. Locker accommodation for 375 persons is provided in each.

The main locker room also contains two circular ablution troughs with a paper towel dispenser and waste bins between. The toilet accommodation is isolated from the main locker rooms, as shown, and access is provided at each end from either the floor level or below the mezzanine level.

The internal finish is of 6 in. square quarry tiles on the floor and ¼ in. thick glazed tiles fixed to the plaster with patent adhesive were used for the wall finish of the toilets, the plaster being decorated with wall paint for the ablutions and locker rooms.

For the suspension of services "Unistrut" fixing channel was provided at 7 ft. 6 in. centres. In all, ten miles of this form of fixing had to be secured to the main floor structure, generally by intermittent welding direct to the filler joists.

Fig. 12.
Whole area loaded to 60 lb. per square foot.
Maximum deflexion 0.86 in.

Fig. 13.—Wood wool roofing panels.

All external walls are constructed of 11 in. cavity walls, the external skin being of Devonian red facing brick and the inner skin of flettons, both being reinforced every fourth course.

For the assembly building proper, patent glazing has been used. Purpose made casements have been fitted to the facilities block and for a large proportion of the ancillary buildings.

Services

The steam supply for both process and space heating is supplied to a point in the services terminal building by the Ford Estate Services, and from that building these services are carried to the new assembly building on pipe gantries.

Steam is supplied at 100 and 200 lb/sq. in. The former for the purposes of supplying the process requirements including the phosphate machines and paint spray tunnels in the paint shop, together with all direct and indirect heating, hot water supply via calorifiers and cooling equipment in the facilities building; the 200 lb/sq. in. supply is for the sole purpose of supplying the steam operated drying ovens in the paint shop at first floor level.

All condensate from both the steam services is returned to duplicate condensate tanks installed adjacent to the services terminal building, and a cooling plant is installed to ensure that the condensate can be handled adequately by the condense return pumps. Special arrangements have been made on the condense return system so that water may be automatically discharged to drains in the event of contamination.

The compressed air distribution system is served from the compressor house on the south side of the site. The system has been designed to supply approximately 8,000 cu. ft. of air per minute at a pressure of 100 lb/sq. in. for various process purposes including the operation of portable tools. There are also three further compressors each supplying 1000 cu. ft. of air per minute at 100 lb/sq. in. and fitted with special air drying equipment. These supply air for spray gun purposes in the paint shop.

Gas is supplied to the new assembly building from a gas meter house on the north/east corner of the site, in which three gas meters are installed, each having a capacity of approximately 70,000 cu. ft. per hour. Gas is supplied to the meter house by the North Thames Gas Board with a 12 in. diameter medium main.

The gas meter house is linked with the new assembly building by an 18 in. dia. main operating at a pressure of approximately 8 in. W.G. Gas is supplied to the new assembly building largely for the purpose of supplying the gas heated ovens in the paint shop at first floor level, together with certain cooking equipment in the facilities building.

The estimated gas consumption is in the order of 150,000 cu. ft. per hour.

The building is served with cold water from a high level water tower in the south-west corner of the site, which is linked with the building by an 8 in. dia. main. The internal cold water distribution, which includes a 6 in. dia. ring main, serves domestic, process and fire-fighting requirements, together with a series of storage tanks installed on the 'C' level roof, from which down services feed the various suspended toilets with cold water. The estimated water consumption of the building is in the order of 20,000 gallons per hour.

The original estimated water consumption was double this figure, but the introduction of a water teatment plant, for the purposes of supplying both clarified and demineralised water to the wet sand decks at first floor level, had an effect of reducing the estimated water consumption by about 50 per cent. It is now possible to return water used on the wet sand decks to the water treatment plant for re-use.

The whole of the ground floor, the trim and assembly sections of the building, is warmed by air supply from the ventilation plants situated on the north side of the lower roof. Each ventilation plant is equipped with duplicate fans and ancillary equipment; one set of equipment for summer ventilation, the other for winter use. Each winter plant is capable of handling 20,000 c.f.m. and each summer plant 60,000 c.f.m. Both summer and winter plants are complete with fresh air inlet dampers, automatic oil filter, heater

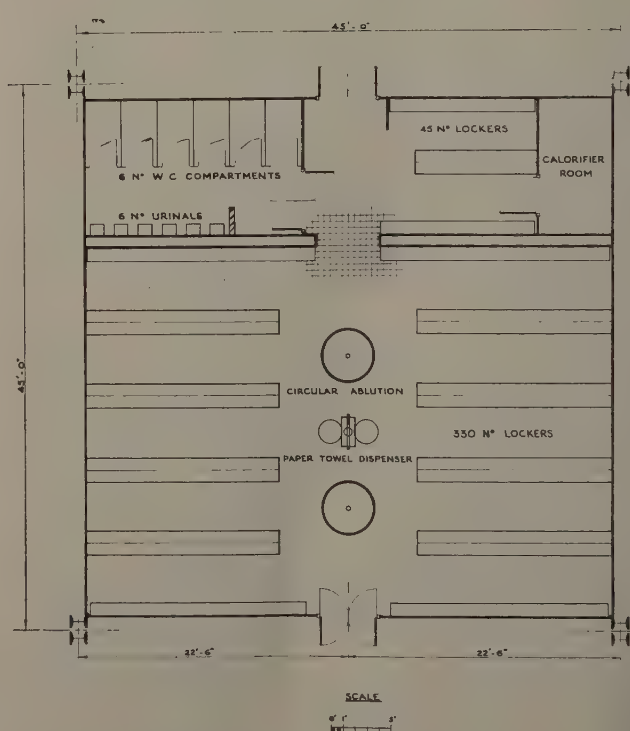

Fig. 14.

battery and interconnecting ducting and automatic control system. The system is designed to provide approximately one and a half air changes per hour in the winter and five air changes per hour in the summer. Ventilation for first floor is approximately six changes per hour in working areas only.

Separate distributing ducts are carried from each winter and summer plant at high level, within the depth of the lattice girders. The summer ducts are provided with high level adjustable air diffusers, whereas the ducts from the winter plants are provided with dropping ducts at intervals terminating with adjustable louvres designed to discharge air in a horizontal direction at a height of approximately 10 ft. above ground floor level.

The extract ventilation system to the ground floor comprises a number of roof extract units fitted in the 'B' level roof and a number of extract ventilation units comprising a range of ducting and fitted with axial flow type fans.

Five plenum ventilation plants and eight plenum units have been installed to supply warmed air to the paint shop floor for space ventilation purposes. A number of roof extract fan units have been installed at normal roof level for the purposes of exhausting vitiated air. In addition to this ventilation equipment, approximately twenty-five warm air replacement plants are installed on this roof, to supply air to the various spray tunnels for process purposes. All air introduced is exhausted via extract fans provided with the paint spray tunnel plant. All the ventilation plants installed for process purposes on this floor are similar in general to the plants at lower level, but in certain cases additional electrostatic filters are installed to ensure dust-free air conditions.

The services to the facilities building include plenum ventilation to the dining rooms and extract ventilation to the kitchens at ground and first floor, together with direct low temperature hot water heating and domestic hot and cold water services.

The kitchens at ground and first floor and the tea kiosks are provided with gas, steam and condense, hot and cold water services.

The various ancillary buildings, including the compressor house, water treatment plant and de-rusting plant are provided with direct heating supplied from the steam distribution system.

The paint mix and store building is equipped with a plenum ventilation plant for the supply of warm filtered air, and extract fans of the propeller type are fitted in the south wall.

The car despatch office, situated in the south-west corner of the site is heated by means of a low temperature hot water system.

A petrol storage system has been installed to supply petrol to the pumps situated under the canopy adjacent to the car despatch office.

The petrol dispensing points in the new assembly building are supplied from pumps installed in a pump house at the west end of the building.

An oil storage is situated in the north-east corner of the site, in which is installed a number of storage tanks and circulating pumps for the purposes of supplying various grades to the new assembly building for gearboxes, rear and front axles, etc. The oil is pumped via a distribution system installed at high level to dispensing points adjacent to the assembly lines and to ensure the free flow of oil at all times, steam and electricity heated tracer lines are installed adjacent to the oil lines.

Electricity is provided at 11 kV. with a capacity of 21,000 kVA and is served from the Ford plant power house. Two 11 kV. feeders serve the site terminating at two 10,500 kVA reactors in the main substation. The 11 kV. switchboard is designed with duplicate busbar facilities enabling the feeder switching to be balanced and arranged to suit loading conditions. From this switchboard separate feeders are taken to serve two 11 kV/3 kV/2,000 kVA transformers and one 11 kV/400 v./1,500 kVA transformer in the main sub station; two 11 kV/400v./1,500 kVA transformers in each of the four roof substations. The 3 kV. transformers in the main substation and a feeder for the 400v. supply serve the compressor house installation where 2,500 h.p. is required.

The 400 v. transformer and the main substation serve two 75 kVA rotary Hi-cycle sets which supply electric power for machine tools at 110 v. a.c. with a frequency of 143 cycles per second, and is delivered throughout the factory by an overhead busbar system with appropriate tap-off points at strategic positions along the production lines. The four roof substations each serve a quarter of the building with power and lighting, serving the plant rooms for the paint spraying floor, ovens and the heating and ventilation plants. The total demand for the power services is in the region of 9,500 kVA and for the lighting 2,500 kVA. The lighting comprises two 5 ft. fluorescent lamp fittings spaced at 9 ft. 0 in. × 11 ft. 3 in. modules throughout the two floor areas, giving 30 foot candles at a working plane of 2 ft. 9 in. above floor level and is designed for twenty fittings per 45 ft. × 45 ft. bay mounted at 18 ft. above floor level.

Roadway lighting throughout the approach and service roads, car parks and vehicle standing spaces is Class "A" 140 w. sodium discharge lighting with photocell operation. The supporting standards are concrete columns with 5 ft. extended arms, giving a lamp mounting height of 25 ft.

The communication services comprise telephone, teleprinter control system, time and recorder clocks and audio warning and programme signal circuits. The fire alarms are wired to indicator panels at important positions over the production area and finally in the fire station. The alarms are zoned to localise action to the "call" area.

Lighting in the offices in the facilities block is concealed in a false ceiling and distributed at an intensity of 25 foot candles. Electricity serves only a portion of the kitchen equipment. An underfloor and wall ducting system provides telephone and small power distribution facility in the offices whereby in any change of office arrangement the services can easily be adapted, diverted or extended without undue disturbance. Power requirements in the ancillary buildings is of the order of 500 h.p. Due to the special conditions in the paint mix, the power installation for this building is of a flame proof type.

Conveyor Bridge

The design and construction of the main conveyor bridge has interesting features in that a constant temperature and humidity has to be maintained to ensure that no oxidisation occurs on the car bodies in the "white" state, especially when the plant is shut down for short periods with bodies in transit.

Fig. 15 shows a cross section of the typical conveyor bridge structure and Fig. 16 gives a view of the finished interior with the overhead conveyors in position, and Figs. 17 and 18 show the partially erected steelwork and the elevation over Kent Avenue.

The roof is formed of steel channel reinforced wood wool slabs screeded and felted as previously described. The eaves upstands are of pressed steel overlaid with bituminous felt.

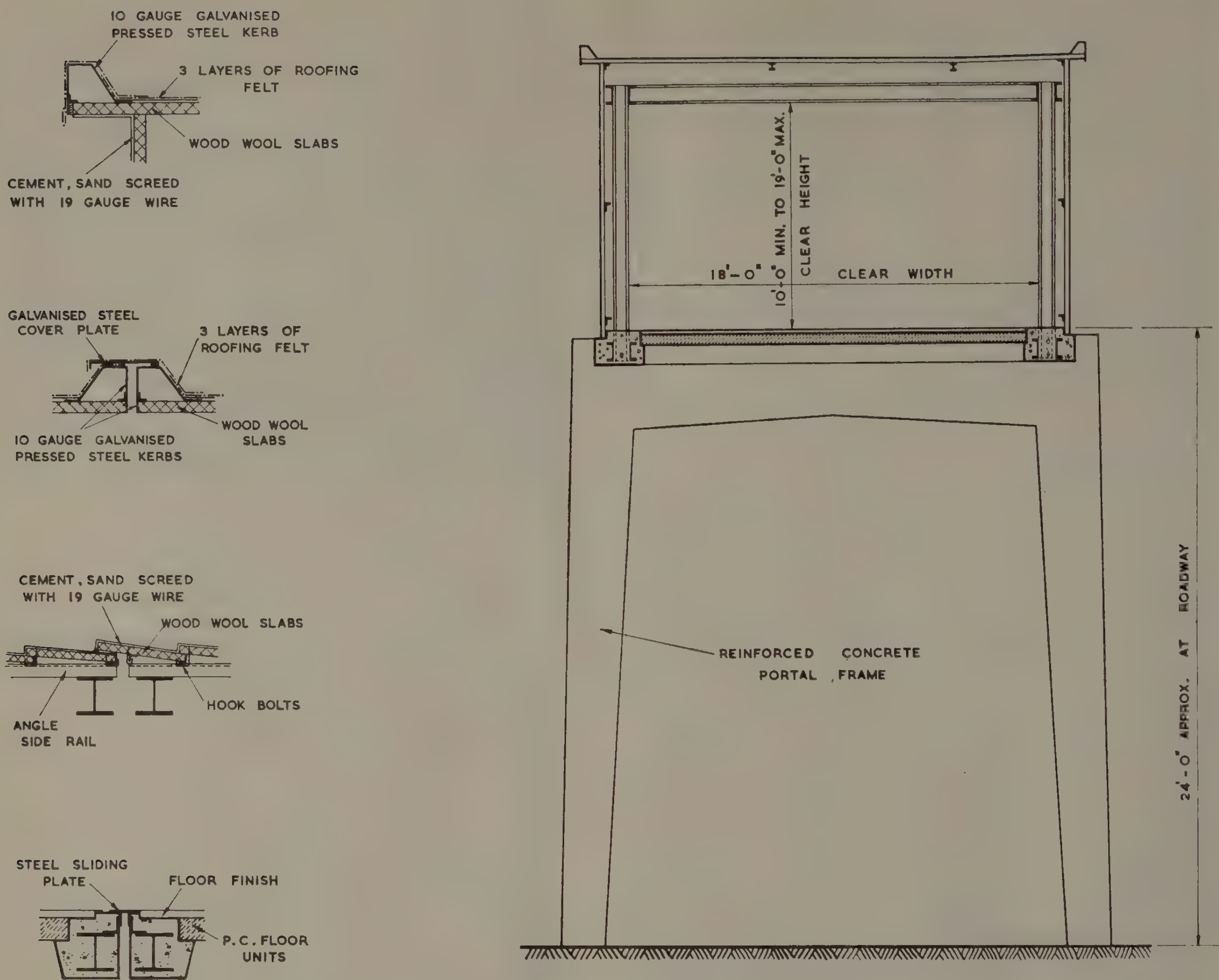

Fig. 15.—Section through conveyor bridge structure.

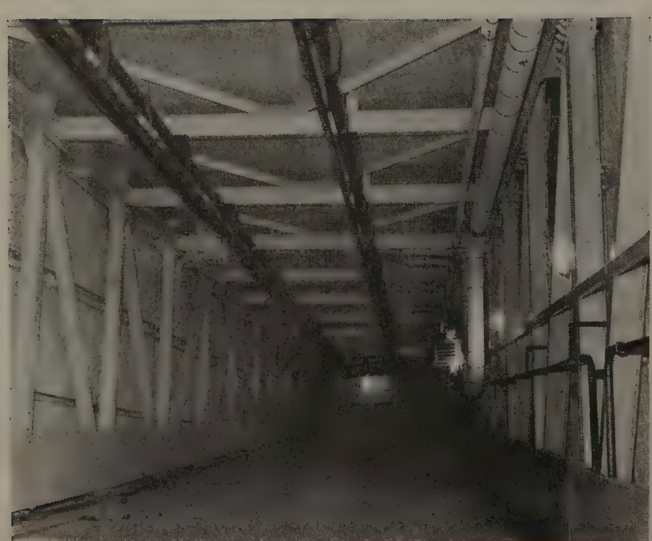

Fig. 16.—Interior view of Conveyor Bridge.

The side walls are constructed of normal 2 in. thick wood-wool slabs laid in a vertical weatherboard effect by overlapping on 2 in. × 2 in. × $\frac{1}{4}$ in. rolled steel angles placed vertically over horizontal side rails. The external surface is then wired with 19 gauge 2 in. mesh galvanised wire and rendered to $\frac{1}{2}$ in. thick with 4 : 1 sand/cement mortar.

The internal surface is skin rendered to seal the surface of the wood-wool between the vertical angles and then decorated.

The main bridge structure is of steel lattice girder construction, tapered where necessary to give the correct floor and ceiling levels of the buildings at each end of the bridge.

Reinforced concrete portal frames were used for the main support resting on piles. The horizontal forces are taken at the angle returns which are formed into stiff corner towers, the steelwork on the long leg being allowed to expand away from the tower to a controlled expansion joint approximately in the centre.

This form of construction proved quite economical for the conditions specified. The overall cost of the conveyer bridge complete, including piled foundations was £57,000 for a length of 725 ft.

Fig. 17.—Partially erected steel for Conveyor Bridge.

Ancillary Buildings

A brief resumé of the construction of the ancillary buildings and their function in relation to the main assembly now follows.

The paint separator is a large underground tank 128 ft. long by 32 ft. wide by 20 ft. deep and houses a scraper conveyor which skims the paint sludge from the surface of the cleansing water returned from the paint spray booths and elevates the sludge into specially constructed skips which are hoisted to the ground level by an overhead runway in the control house.

Fig. 19 shows typical sections through this structure and Fig. 20 is an internal view. Based on previous experience of the ground strata underlying the site from work of similar nature on an adjacent site, steel sheet piling was driven to a toe depth of 50 ft. into the sandy clay; with the piling at this depth, sufficient impedance is presented to the ground water to render the draw down curve, such that only small quantities of water penetrate into the excavation, which can be dealt with by small pumps.

The whole structure has been designed against flotation at the normal standing water level by dead weight only when the separator chamber is empty.

The bottom concrete is 4 ft. thick and is stiffened by reinforced concrete division walls dividing the separator chamber into three longitudinal compartments, each housing a scraper conveyor.

The inner surface of the concrete was rendered for watertightness by a proprietary system.

The paint mix building is of brick clad, steel framed construction similar to the main building, and is 158 ft. long by 30 ft. wide by 40 ft. high, divided by a first floor with a ground to floor height of 21 ft. This floor is of filler joist construction and the roof is designed to carry a super load of 100 lb/sq. ft. on precast concrete units.

A battery of pipes in the form of ring mains completely circle the paint floor, each pipe being for one colour, and connection can be made at each spray booth position.

The purpose of the paint mix building and plant is

Fig. 18.—Conveyor Bridge.

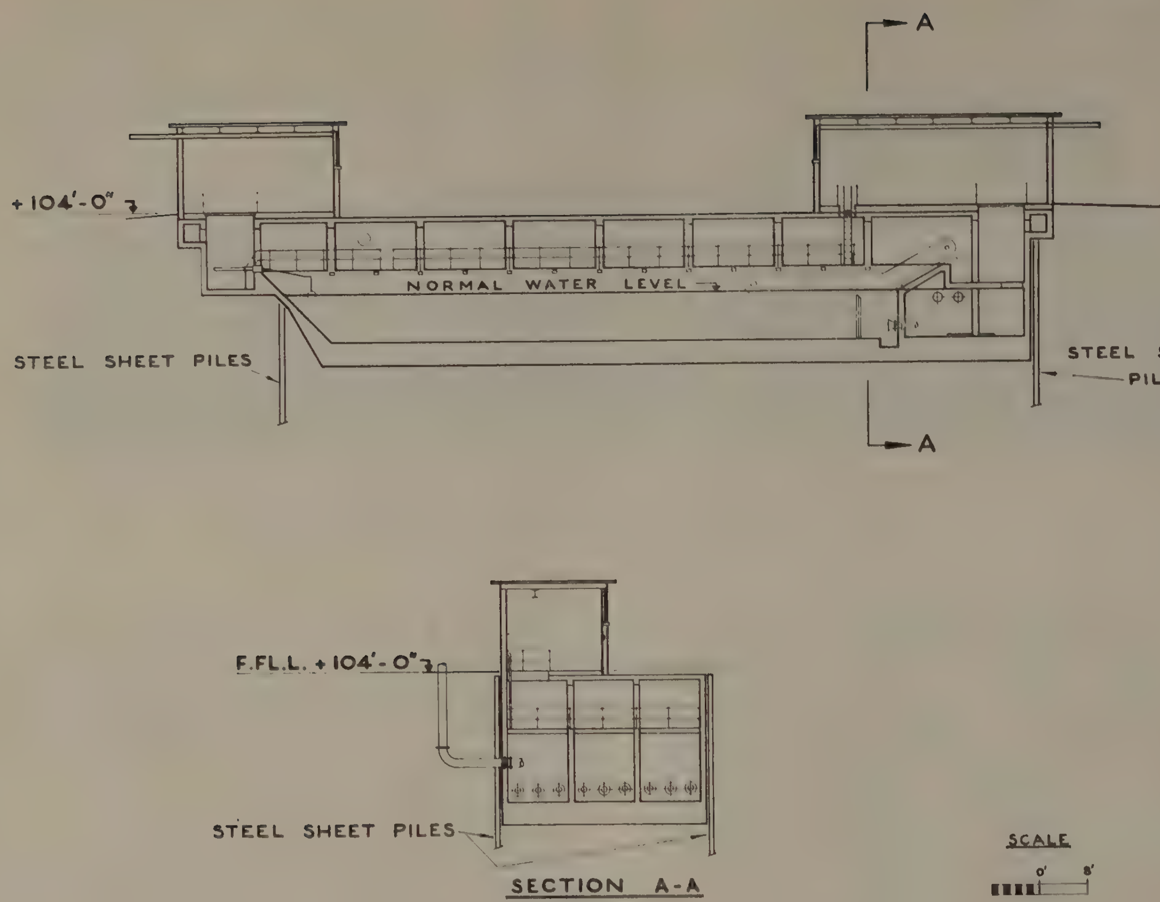

Fig. 19.

to receive, store and mix all paints used, and deliver these into the ring mains via the paint pipe service bridge between the main and paint mix buildings.

The compressor house supplies all the compressed air required for the operation of the plant. A capacity of 11,000 cu. ft. of free air per minute is provided by three 1,000 cu. ft. per minute and four 2,000 cu. ft. per minute compressors.

Each compressor is isolated from the main structural slab by forming pockets into which the concrete base carrying the compressor is recessesd, with the bottom and four sides insulated with cork.

The weight of a 2,000 cu. ft. compressor complete with the motor is 18.5 tons and the weight of the concrete base is 31.6 tons giving a compressor/base weight ratio of 1.7 insulated from and independent of the main structural concrete. Fig. 21 shows an internal view of the compressor house.

The services terminal building houses the steam distribution plant receiving from the main Ford Motor Company's supply and breaking down to the various process mains already described.

The demineralite plant provides chemically pure process water for use on the wet sand decks for cleansing

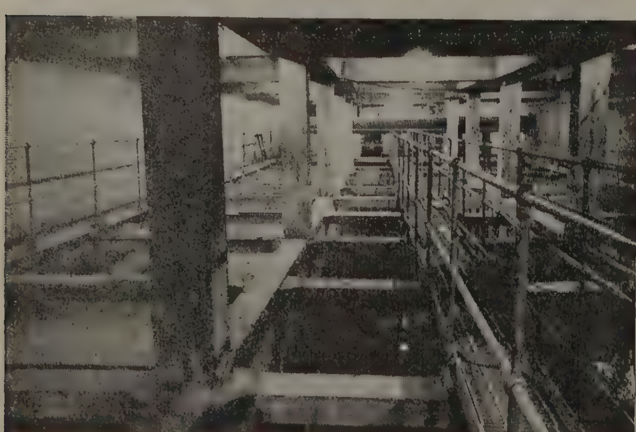

Fig. 20.

Fig. 21.

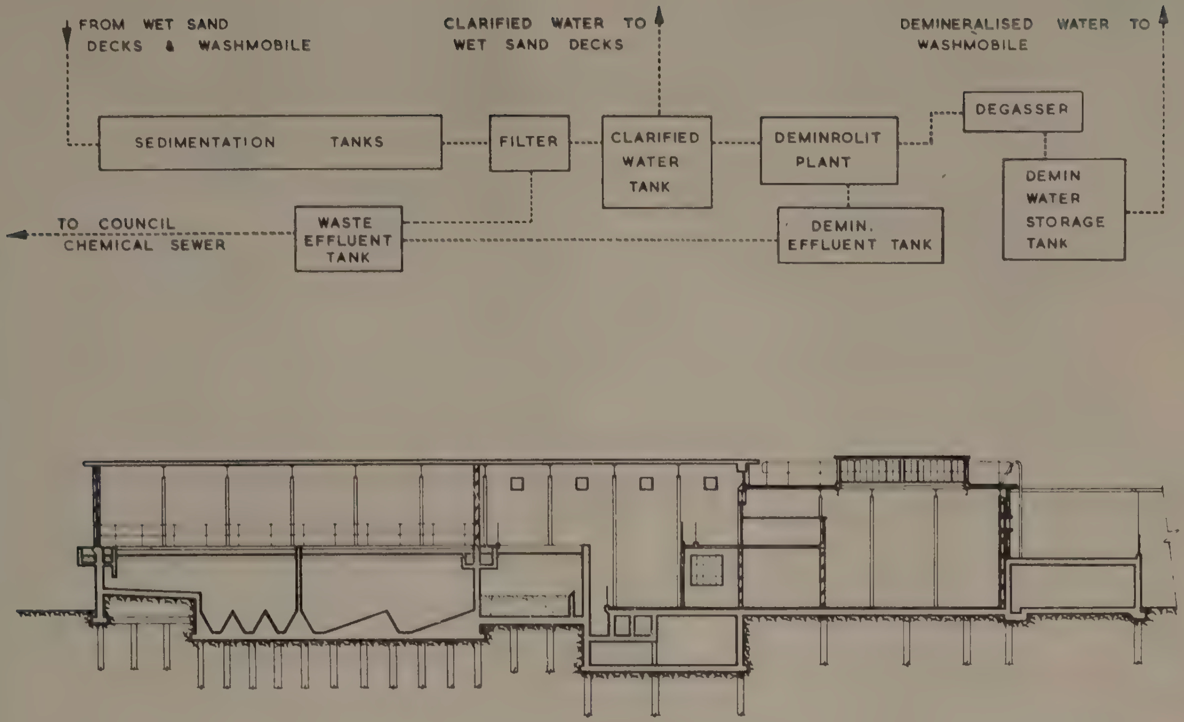

Fig. 22.—Water Treatment Plant.

the car bodies in the process of rubbing down the paintwork. The process employed is that developed by Messrs. Permutit, and the flow diagram for this together with the cross section of the civil engineering work to accommodate the plant is shown in Fig. 22. The superstructure is similar in construction to the main building.

The car despatch department is for the final handling of cars before leaving the factory and is composed of offices for the reception of collectors, toilets and a cashiers' section. A light glazed canopy 33 ft. span by 42 ft. long is provided on the south side.

The fire station is sited at the north-west corner of the site and houses the mobile equipment operated by the fire protection department of The Ford Motor Company. This department is responsible for all fire precautions in the plant.

Fire Protection

Protection against fire is a difficult problem in any industrial building. In the motor industry where large open areas are required to lay down the long conveyor lines associated with automation and mass production this protection must be such that a fire if it does unfortunately start, can be immediately confined to a local area.

The fire protection department called for sprinkler installations to all the main buildings on the site, together with 80 first-aid hose reels, which can be used by any works personnel, and sixty-four main hydrants. All the hydrants and first-aid reels are located at various points on the site and in the building to give suitable cover to any area.

Small hand appliances are provided on every building stanchion on the ground and first floors of the main building and in ancillary buildings where specified.

Approximately twenty-six miles of sprinkler pipework have been installed with 16,000 sprinkler heads set in the majority to break open at a temperature of 155° F.

Sprinkler and hand appliances are also installed within equipment which carries special risk from the fire angle.

In the substations, slipper dips, dump tanks and paint mixing rooms where special precautions must be taken, CO_2 installations are provided.

The assembly building itself has fire exits so placed that all personnel can be cleared in three minutes from the sounding of the 44 fire alarms which in turn are linked to the Tannoy system and the fire station.

A staff of six full-time fire protection personnel are on duty each shift and these are backed by security personnel and certain maintenance staff trained in the use of fire fighting equipment.

Roadways

All external roadways were constructed on the rolled fill material topped with 2 in. thick hoggin on which was laid a 9 in. thick concrete slab reinforced with two layers of 7.32 lb/sq. yd. high tensile steel mesh with a minimum cover of 1½ in. to the top and bottom of the slab. The final wearing coat is of 1½ in. thick bitumen macadam laid after the main construction work on the site was completed.

Dummy expansion joints at 30 feet centres are provided in the concrete slab formed of 1½ in. deep by ½ in. wide grooves tranversely across the full 22 ft. width of the roadway and filled with ½ in. thick elastic seal. Generally, the slab was cast with a longitudinal construction joint in two 11 ft. strips making a total width of 22 ft. with the main expansion joints at between 150 to 180 ft. centres. A typical cross section of the road construction is shown in Fig. 23.

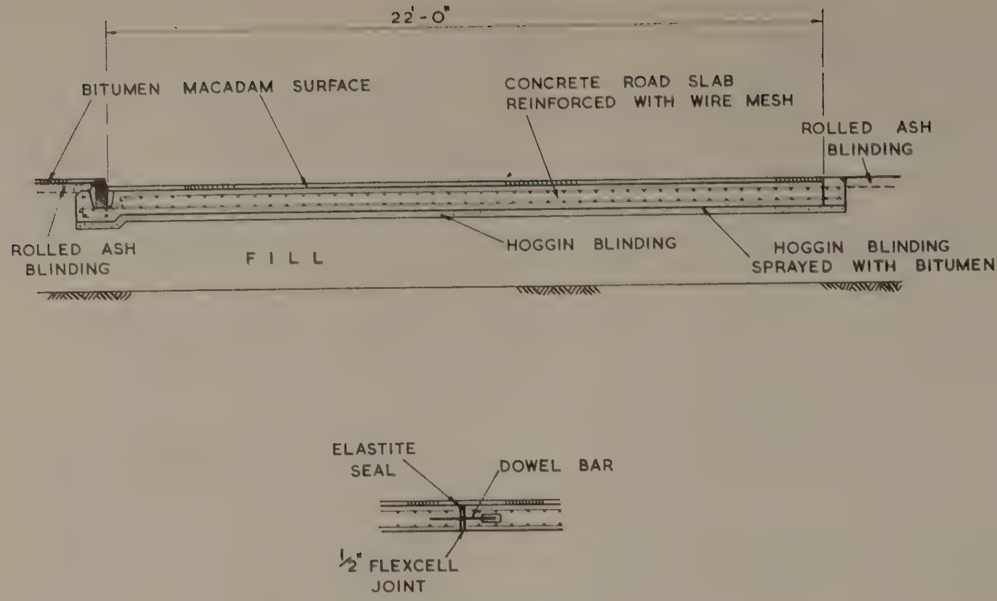

Fig. 23.

Construction

The building was let in four successive contracts with commencing dates and completion times as follows :—

	Commencing date	Completion
1. Site Works, Roads, Sewers and Test Piling	June 1956	50 weeks
2. Piling	July 1956	26 weeks
3. Foundations and Ground Floor Slab	Jan. 1957	50 weeks
4. Superstructure, including Ancillary Buildings	July 1957	78 weeks

Completion of the scheme was required by early 1959 including installation of the majority of the clients' processing plant.

The main quantities in the first three contracts to ground floor level were as follows :—

Site Works	
Filling	200,000 cube yards
Drainage	12,000 lineal yards 4 in.—42 in. dia.
Ducts	1,000 lineal yards
Concrete Roads	1¼ miles
Piling	7,500 No. 14 in. × 14 in. 22 ft. to 46 ft. in length
	1,300 No. 12 in. × 6 in. Sheet Piles
	160 No. 24 in. × 9 in.—ditto—
Foundations & Ground Floor	Concrete, 32,500 cube yards
	Reinforcement, 2,300 tons
	Do. Fabric, 50,000 sq. yds.

Progress on the building as a whole demanded that operations should commence at the centre working outwards in both directions along the length of the building. The central section was required by June 1957 in order to commence erection of the paint spray booths, which required the longest time to install of any plant in the factory. This also suited the structural steelwork erection programme which enabled progress on the full width of the building travelling out 600 ft. in each direction.

Site Works

Work commenced at site with the drainage. The main drainage is shown in Fig. 7. Where clear of the factory area, flexible jointed concrete pipes were used for all diameters. The pump wells for the pumphouse were constructed within steel sheet piled cofferdam taken 30 ft. in depth. Filling was obtained from the main surplus spoil dumps on the Ford Estate situated about 1½ miles from the site. This contained a high proportion of used foundry core sand and gave a material with good surface drainage and provided a good running surface for construction traffic over the site, except that in dry weather it became very dusty and had to be constantly watered down.

The filling was excavated at the dumps by normal excavator methods, face shovel or skimmer, and transported to the site by tipping lorries, spread by D8 bulldozer and compacted in 9 in. layers by 8 to 10 ton rollers.

The average quantity of filling handled per day was 900 cu. yds.

The general finished filling level over the site was brought up to within 3 in. underside of the floor slab construction approximately 4 ft. above original ground level, and excavation for pile caps and stanchion bases carried out through the fill after piling was completed, the surplus so obtained being spread to make up to underside of the ground floor.

Test piles were included in the site works contract, approximately one to every 10,000 sq. ft. of floor area, for purpose of determining the probable lengths of piles for the piling contract.

Piles were specified to be either reinforced or prestressed concrete 14 in. × 14 in. in section and required to be driven to sustain a working load of 50 tons per pile. The general set adopted was 2 in. for the last 10 blows of 2 ton hammer falling 4 ft.

Actually 69 were driven, 8 No. 30 ft. in length, 18 No. 35 ft. and 42 No. 40 ft. Sixteen of the test piles required to be dollied down to obtain the required set.

This showed the presence of rifts in the ballast stratum, the top of which was generally at an average depth of 20 ft. below the original ground level, due to old stream beds over which the peaty clay stratum had been deposited at a later date.

The data obtained from the test pile driving was

by no means conclusive in determining accurately the lengths of the piles and in several locations piles required to be lengthened during the piling contract due to unsuspected rifts in the ballast which had not been disclosed by either the borehole or test piling results obtained.

Piling

The majority of the piles used on the site were prestressed concrete. These were factory cast and could be delivered within a week of casting and driven within three weeks. Four diesel driven pile frames were employed travelling across the width of the building on the lines of the ground floor bearing piles at 15 ft. centres. These were supplemented by two excavators with false leaders driving vertical and raking stanchion base piles where off centre with the floor pile lines.

Piles were led to the frames by tractors and trailers travelling over the site and lifted to the frames by crawler cranes.

Where raker piles have been used in the stanchion pile caps, these were driven at 2 ft. 6 in. centres at the top, raking outwards from the pile cap. In certain cases, generally where services already existed or had been installed before the piling could be determined, e.g. under the Facilities Block, the ground was prebored to a maximum depth of 20 ft. by a 14 in. diameter truck mounted power driven auger, the pile then being pitched in the hole so formed and driven to set. In addition, some 150 in situ piles were installed where headroom was restricted by overhead transmission lines that could not be diverted for some time.

The piling was completed within the six months contract time demanding an average daily progress of fifty piles driven per day.

Foundations and Ground Floor Slab

The concreting programme called for a weekly output of approximately 700 cu. yds. The 32,500 cu. yds. of concrete in this contract was composed of :—

4,000 cu. yds. in concrete blinding.
6,500 cu. yds. in stanchion bases and other foundations.
22,000 cu. yds. in ground floor slab.

Three classes of concrete were used in the foundations and floor work, and were specified for materials to be proportioned by weight and minimum crushing strengths at 28 days giving :—

Class B.	3750 lb/sq. in.
Class C.	3000 —do—
Class F. 1 : 12	

Class F was used entirely for concrete blinding and mass concrete filling, Class C generally for pile caps, stanchion bases and structural floor slab, and Class B for certain of the liquid retaining structures.

Two 1 cu. yd. weighbatch plants were set up on the north side of the site centrally with the length of the building, adjacent to the main public road which gave easy access for the concrete material supplies. One of the plants used cement supplied in bulk lorries and the other was adapted to use pressurised cement. Aggregates were fed to the hoppers by ¾ cu. yd. grabs on crawler cranes.

A laboratory was located adjacent to the mixing plants with all apparatus for concrete quality control to test grading and quality of coarse and fine aggregates, moisture contents tests were taken daily on aggregates and sand, and a 200 ton compression testing machine was installed for crushing of test cubes at site. The temperature of the laboratory was thermostatically controlled and also the water storage tanks for the curing of cubes.

By far the majority of concrete used throughout the work was Class " C " and after tests on preliminary trial mixes, the aggregate cement ratio for this grade was agreed at 6.6 The range of water cement ratio was 0.48—0.55 and slump 0 in.—2 in. according to temperature conditions and type of work.

Six test cubes were taken daily, two of which were tested at 7 days and four at 28 days. The average strength of test cubes throughout the period of the contract was 4300 lb/sq. in. there only being one failure and that in frosty weather. At one period concreting had to be carried out under freezing conditions which was accomplished under canvas canopies with hot air blowers maintaining the general temperature to above 40° F.

Concreting commenced with the stanchion bases and ground mat which required to be always well ahead of the floor slab work. Brick on edge or 4½ in. brickwork was used as back shuttering to the stanchion bases and left permanently in position. Concrete was transported from the central mixing plant to locations of the stanchion bases by telehoist lorry, the swivel chutes on these enabling concrete to be placed directly where required. Approximately 1,000 sq. yds. of ground mat was required to be placed daily and the spreading of this quantity 2 in. thick required to be considered mechanically, and finally Amann spreading machines – usually used for tarmacadam laying—were adopted successfully.

The concreting of the ground floor slab followed working outwards from lines 16-17 and concentration was centred on the completion of bays 12-22—a 450 ft. length of the building. This area was required in 16 weeks so that derricks could be set up on the floor slab for the commencement of structural steelwork erection.

It was decided to concrete in bays 15 ft. wide, one third of the 45 ft. stanchion base module, in the north-south direction across the 585 ft. width of the building, excluding the Facilities Block, giving a quantity of approximately 275 cu. yds. in the bay, which was possible to complete as a daily pour. In view of this quantity, it was decided to adapt travelling spreading and vibratory finishing machines, usually used on road and airfield runway work, for the placing and compacting of the concrete. The reinforcement in the slab followed a regular pattern in standard floor panels so that it was possible to slot vertically rail mounted steel road forms to pass over the reinforcement, generally at 15 in. centres, and these were stiffened after the slotting by a longitudinal splayed timber bolted centrally, which also served to form the rebated construction joint in the edge of the slab. The 15 ft. lanes were set out central with the stanchion base and floor pile cap centre lines and edge shuttering was fixed around stanchion base walls, areas where pits were to be constructed were blocked out by shuttering, and prefabricated expansion joint assemblies were placed in position, so that concreting could be carried out continuously throughout a lane. Any special deep construction such as subways, drive pits and machine foundations were constructed after the ground floor slab.

The floor concreting was commenced between lines 13-14 and 18-19 on two 15 ft. bays 180 ft. apart. These were poured by concrete pump and served as pilot bays and when these were sufficiently cured the lorry transport was put into operation over the pilot bays and the hoppers of the spreading machines fed direct by telehoist or side tipping lorry for the bays on either side of the pilot. The concrete was compacted by two passes of the finishing machine, the general

water cement used being 0.52. A very smooth finish was not required for the structural slab in view of the 3 in. topping surface slab to be placed later. Mushroom pile caps to the floor slab were poured at the same time as the slab and poker vibrated. After completion between lines 12-22 concreting proceeded outwards in each direction to complete the building area in like manner.

The 3 in. final slab over the structural slab was of 1 : 2 : 4 mass concrete finished granolithic. The specification for the surfacing was that three parts of ½ in. down granite aggregate to one part of cement should be thoroughly mixed dry and then spread evenly whilst still dry over the top slab concrete, within half an hour of placing the latter, and well tamped in until moisture is drawn through and the surface could be trowelled.

The surface of the structural slab was thoroughly scarified by rotary rock drills dual mounted in travelling carriages, the average depth of surface penetration being ¼ in. The surface was then cleaned by compressed air and water jetting and a layer of thick grout poured over immediately prior to concreting. Concrete was laid in bays 15 ft. wide continuously as for the under slab, 1 in. dummy joints being provided at 20 ft. centres at the base of the slab, to induce shrinkage cracks only on the line of the joint. The concrete was tamped ⅜ in. below the finished surface level required and the dry granolithic mixture then thoroughly tamped until slightly moist on the surface and trowelling could be carried out without working laitence to the surface. When sufficiently cured, the surface was treated with a proprietary surface hardener.

Pits and tank structures greater than 8 ft. in depth from ground floor were treated as water retaining structures. The subways for access from the facilities block to the main building were constructed within 12 in. × 6 in. prestressed concrete sheet piling left permanently in position. These were of the interlocking vee joint type with a 2 in. × 2 in. birdsmouth on the acute angle of the pile. This formed a square recess in the sheet piling when driven down through which a grout tube could be passed and the interlocks of the piling were pressure grouted with 1 : 1 cement sand grout, and the vertical joints pointed on the internal face. Asphalte tanking was then applied in three coats over the ground mat and internal face of the piling and the reinforced concrete structure constructed within the tanking. Three such subways were provided 2-130 ft. long and 1-105 ft. long. The length of piles used was 28 ft. driven to level and the finished internal dimensions were 10 ft. 3 in. wide by 8 ft. deep.

Similar construction was used for the concrete pits containing the paint dump tanks, of which three were installed. A heavier section of sheet pile was used, namely: 24 in. × 9 in. due to the greater depth of excavation, which was up to 15 ft. deep.

Superstructure

Structural Steelwork formed an independent contract and was erected by six travelling derricks, three set up across the building to control the 405 ft. width of the two-storey section of the building. Erection commenced on lines 16-17 and the derricks travelled outwards simultaneously in each direction. On completion of the two-storied portion, erection then proceeded on the single-storey section to the limits of the main building area.

The total weight of steelwork involved was 16,500 tons, which progressed at an average erection of 450 tons per week and was completed in 46 weeks, including the time for erection of plant.

Suspended Floors and Roofs

The types of construction used were mainly divided as follows :—

Filler joist floors	490,000 sq. ft.
In situ reinforced concrete floors	101,000 sq. ft.
Pre-cast concrete floors and roofs	237,000 sq. ft.
Wood-wool roofs (main)	233,000 sq. ft.
Wood-wool roofs (monitors)	120,000 sq. ft.

At the time of commencing the first floor and roof construction, concreting of the foundations and ground floor areas was still in hand towards the extremes of the building, so that a separate concreting plant was set up centrally on the south side of the building consisting of two 21/14 weighbatch mixers using pressurised cement, aggregates being handled by electrically operated drag shovels. By this time the roads to south of the main factory area had been completed for delivery of materials.

The mixers fed to two skip hoists discharging at first floor and roof level into two-cube yard and one-cube yard receiving hoppers. These delivered into ½ cube yard dumpers and power driven barrows respectively for the first floor and roof areas to distribute concrete to the locations required. On completion of all ground floor work, the south side mixing plant was dismantled and the superstructure served by the original 2 cube yard batching plants.

The programme demanded completion of an area of first floor 405 ft. by 45 ft. every 10 days. Concreting was carried out from north to south in bays 15 ft. wide as previously. The filler joist floors were 7 in. thick with a monolithic grano finish as for the ground floor.

Unrestricted access was required to the ground floor underneath whilst concreting was in progress so that other trades could work unhampered, and also it was characteristic of the clients that as soon as a substantial floor area was completed they required to occupy it either for plant erection or storage. To obviate the use of shores or props from the ground floor a scheme of precast concrete shuttering was developed for the filler joist floors, the shuttering being left permanently in position.

The standard size of shutter panel adopted was 2ft. 4½ in. × 2 ft. 0½ in. × 1½ in. thick weighing 87 lb. The panels were formed of 1 : 2 : 4 concrete with ⅜ in. aggregate and reinforced 1.83 lb/sq. yd. fabric. Casting was carried out in the Contractor's depot about a mile from the site on storage shed floors which were smooth enough to ensure a finish to the soffit of the precast units capable of taking paint. The tops of the panels were left rough for bonding with the in situ concrete of the floor, and 10-gauge wire loops were cast in for lifting of the units, the loops being tied to the floor reinforcing fabric when the units were fixed.

Prior to mass manufacture of the present shutters tests were made on sample panel sloaded to 1½ cwts./sq. ft. as equivalent to the maximum construction loading expected, and a sample bay of filler joist floor was constructed and tested to 3 cwts./sq. ft. without any failure. This bay was then broken out to observe the bond between the precast panel and the in situ concrete above which proved satisfactory.

Shuttering plans were drawn out for each 405 ft. × 45 ft. bay to be constructed showing the positions of all floor openings, staircase wells, etc. on which the number of standard panels and those of special size required were marked, and these were used both for

the manufacture programme in advance and for the fixing at site.

Panels were transported by trailer from depot to the site where they were loaded into cage containers and hoisted to the first floor at the location required. The hoists were of the "Saga" type mounted on a mobile platform and adapted to run on the top flanges of the filler joists as tracks.

As some 70,000 sq. yds. were constructed in all the use of this shuttering system undoubtedly enhanced progress considerably by the time saved in erection, striking and cleaning of timber or metal shuttering at site and obviated delay in obtaining re-use of shuttering during the concrete curing period.

For the areas of normal reinforced in situ floors, usually spanning 11 ft. 3 in. centre to centre of secondary joists, ⅝ in. plywood in as large standard sheets as possible were used as shuttering laid on telescopic beam centres supported on the joists, leaving clear access underneath.

The precast floor beam areas were of the flat hollow box type factory cast and hoisted and set in position by mobile cranes. Generally precasting was brought into use as much as possible in the superstructure work, and eaves and cornices originally designed to be in situ were converted to precast prior to the time required for their erection at site.

Conveyor Bridge

The reinforced concrete supporting towers and portal frames averaged 25 ft. in height from top of pile cap to soffit of the main lattice girders. Concrete was poured continuously within plyfaced shuttering for the legs to the portals to the underside of the transom, a height of 22 ft., the transom forming the second pour.

The main steelwork lattice girders spanning from these supports were prefabricated and lifted into position at site either from guyed, derrick posts or by mobile cranes at the rate of one span per day, the six main spans being 114 ft. 6 in., 110 ft., 80 ft., 80 ft., 87 ft., 118 ft. After this the cross girders and bracings were site connected, the precast concrete laid and the wood-wool cladding completed.

Acknowledgments

The Authors wish to thank The Ford Motor Company for permission to publish this paper.

They also wish to thank the Partners of Messrs. Posford, Pavry & Partners, the Consulting Engineers, and Directors of Messrs. G. Percy Trentham Limited, the General Contractors of the work, for their permission to give and for their assistance in the preparation of the paper.

A project of this magnitude is never the work of an individual but of a team, and in the publication of this paper they acknowledge the work of the many colleagues both in the design office and on site who have made this work possible. The Authors have the honour of presenting their work.

They also acknowledge the many Sub-Contractors associated with the work, who co-operated in every way to the successful completion of the project.

Book Reviews

Metal Fatigue, Editor J. A. Pope (London : Chapman & Hall, 1959). 9¾ in. × 6 in. 381 + xiv pp. 70/-.

A week's residential course on "The Fatigue of Metals" was held in the Engineering Department of Nottingham University in 1955 with the object of presenting to practising engineers the known facts about metal fatigue and its effects on design. It was suggested that the lectures should be published in the form of a symposium, and in the present volume each chapter represents one lecture, these remaining substantially unaltered apart from purely formal features added for publication, as for instance a standard nomenclature.

The volume is divided into three parts, the first on the fundamentals of fatigue, containing chapters on theory of fatigue failure, criteria of failure under complex stresses, stress concentration factors, residual stresses and their effect on fatigue, cumulative damage, corrosion fatigue and fretting corrosion, crack propagation in steel, and the effect of temperature upon the fatigue properties of steel. The second part consists of eight chapters on the fatigue properties of engineering materials and components, and part three deals with fatigue testing of engineering components. A bibliography of relevant references has been added to each chapter.

This publication, which presents a picture of the present state of knowledge of the fatigue of metals, should be of considerable value both to engineers and to advanced students.

Decay of Timber and its Prevention, 2nd. Edition, by K. St. G. Cartwright and W. P. K. Findlay. (London : H.M.S.O, 1958). 9½ in. × 6 in. 332 + xv pp. 27/6d.

This book is the result of work carried out at the Forest Products Research Laboratory of the Department of Scientific and Industrial Research. Since the first edition was published in 1946 new information has become available, and the new edition has been completely revised and brought up-to-date.

Causes of decay in timber are considered and the principal wood-rotting fungi described. Conditions under which these fungi flourish in standing and felled timber and in timber buildings and structures are explained, and measures for prevention of such damage are suggested. Methods for seasoning, storage and preservation are given, the prevention of decay in plywood in wooden boats receiving particular attention. Chapters are also devoted to the durability of timbers, and to staining and discoloration and its prevention.

Each chapter concludes with a comprehensive bibliography and the book is well illustrated, with ten figures and fifty seven plates.

Lightweight Fire Protection and The Structural Engineer *

by A. R. Mackay, A.M.I.Struct.E.

Synopsis

The paper postulates the proposition that the use of dense concrete casings for the fire protection of structural steelwork is outdated and uneconomical.

Consideration is given to the alternative of using vermiculite/gypsum plaster as the basis of lightweight fire protection; this includes hitherto unpublished data from estimates of the cost of a typical ten-storey building showing the financial advantages in favour of lightweight fire protection.

The prospects for a large scale use of vermiculite gypsum plasters as a means of making steel framed buildings lighter and cheaper are considered, and various general recommendations are introduced for the guidance of structural engineers and others who may be involved in work of this nature.

Introduction

During the past decade there has grown up in the building industry a conviction that a concrete casing for the fire protection of structural steelwork is outmoded, particularly in multistorey buildings.

In the same period, there has been an increasing demand for buildings of ten storeys, or more, above ground level. The majority of these have structural frames designed to carry, exclusive of floor and ceiling finishes or allowances for partitions, a superimposed load of between 40 and 60 lb. per sq. ft. of floor area. Where a steel frame has been employed, cased with concrete for fire protection, the dead weight of the casings, translated into terms of superimposed loads amounts to an additional 18 to 20 lb. per sq. ft. for the internal beam and column casings alone and as much as 23 to 27 lb. per sq. ft. for all beam and column casings.

The figures vary, depending upon the amount of embedment of the top flanges of the beams into the concrete floor slab.

It is possible so to arrange the beams as to reduce the cost and weight of casings, but the apparent savings are simply transferred to the floors and, usually, are not savings at all in the end.

Until quite recently the excessive weight of fire protection has been an accepted handicap; now the problem can be overcome, economically and efficiently.

At the outset of his work on lightweight fire protection, the Author sought out the history of building and building fires in this country to see what lessons from the past could be applied in the future.

It is impracticable to reproduce major building fires in the laboratory and the historians gave some guidance where the laboratory engineers could not.

In the mid 12th century, London, Bath and York were each almost completely destroyed by fire and early in the 13th century there was a second major fire of London. King John issued an Ordinance with the aim of minimising the risk of a similar disaster. This legislation seems to have been the first to recognise, and provide against, the fact that some buildings constitute a greater fire risk than others by virtue of the processes carried on within them. The fire protective value of plaster had been observed, and it is interesting to note that it had won its way into the "Building Byelaws" of the day, over 700 years ago. There were frequent references to plaster being required as a fire protection in circumstances where the fire risk was greatest.

However, King John's Ordinance was not properly enforced and it appears to have been ignored and eventually, forgotten.

The Great Fire of London in 1666, starting in a bakehouse engulfed 13,000 houses alone, in 2½ days, a catastrophe which led to the Rebuilding Act of 1667, the precursor of all building legislation in this country. It also led to the formation of the London District Surveyors who can thus claim a tradition of public service lasting nearly 300 years.

The Great Fire and the Act of 1667 had two important effects on the building industry. They led to the establishment of a brickmaking industry on the clay around London, and to the large scale importation, from Scandinavia, of softwood which more or less ousted home grown hardwood as a structural timber. Because it was easier to work, and possibly because of its cost, softwood was used more economically than hardwood, particularly with regard to thickness. The resultant lowering of fire resistance was counteracted by introducing plastered ceilings.

The next milestone of note was the growing demand for multistorey buildings on the fringes of large towns; a demand which grew during the Industrial Revolution. These buildings had substantial walls, well able to contain a fire. Nevertheless, serious outbreaks continued to occur and it was soon apparent that it was not sufficient to confine a fire to the building in which it started; it had to be limited to the floor, or preferably the compartment, in which it first broke out, for as long as possible.

This problem has exercised the minds of designers and inventors ever since.

Towards the close of the 19th century structural steelwork became available, with specialist firms contracting to supply and erect it, rather as they are known today. During the first decade of the 20th century the reinforced concrete and hollow tile floor was evolved on the lines which have been emulated all over the world ever since. The complement to the steelwork and the concrete floor was a concrete casing which served not only to transmit the load from the floor to the beams, but also as a convenient means of fire-protecting the steelwork. In addition, the casing in its simplest form was a satisfactory basis for plastering and other decorative treatments.

* *Paper to be read before the Institution of Structural Engineers, at* 11, *Upper Belgrave Street, London, S.W.*1, *on Thursday,* 21*st January* 1960, *at* 6 *p.m.*

The historians highlighted two items of special significance among many others.

1. The fire protective value of gypsum plaster has been recognised for almost eight centuries.

2. The concrete casing first evolved in connection with reinforced concrete floors over half a century ago has not changed significantly in a period which has seen a greater evolution of building techniques than any other comparable period in our history.

It is time to reconsider the fire protection of structural steel building frames, and to take advantage of the materials and techniques now available to the building industry, and already tried and tested.

Types of Lightweight Fire Protection

Broadly speaking the types of lightweight fire protection available in this country are in two main categories.

1. Suspended ceilings giving fire protection only to beams.
2. Plasters and building boards or blocks giving individual treatment to each structural member.

Suspended ceilings are commonly formed of plaster on metal lath, or with asbestos or plaster boards secret fixed to light metal sections hung from the main structure. It is essential, whatever fire protective membrane is used, to ensure that it hermetically seals the steelwork in a sandwich whose upper layer will, generally, be formed by the structural floor slab.

If the columns too, are to have a lightweight fire protection, materials from the second category are employed. The joint between column sides and ceiling must be made carefully so that the efficiency of the fire protection is not impaired.

The basic building materials in the second category are similar to those in the first. In order to employ plaster, a metal lath former is first fixed around the beam or column, and the plastering is carried out in the traditional way. Similarly with the various building boards, ingenious clips and other fixing devices have been contrived which enable the board itself to be fixed securely in such a fashion that the structural steelwork and the fixing devices are fully fire protected. With one system there is a combination of plaster board and plaster; yet another, using asbestos sheets can be decorated without necessarily having a skim coat of plaster as the basis for it.

The efficiency of these competing systems giving lightweight fire protection can be assessed, not taking into account their cost, by reference to their performance during a standard fire test; but their efficiency both in terms of fire protection and cost can be measured only by their effect on the cost of finished buildings related to the cost of corresponding buildings with concrete casings around the steelwork. This has been done. It was felt that the comparison of costs would be most valid if the finished internal appearance of the lightweight and concrete cased buildings was identical. For this reason the study of costs was limited in the first place to those materials which give an individual fire protection to each structural member.

A brief digression to define "fire resistance" "fire grading" and "fire load" will be of value.

The functional efficiency or fire resistance of building materials is measured by the time which elapses during the execution of a standard fire test carried out in the manner prescribed in a British Standard, BS 476: Part 1: 1953 "Fire Tests on Building Materials and Structures."

The fire resistance is the period of time during which a complete element of a structure continues to fulfil its function while subject to the heating conditions that prevail during an actual building fire; without regard to the individual performance of the various materials making up the structural element concerned.

The standard of fire protection required in a building is related directly to the fire load it carries. The fire load is the number of British Thermal Units which could be liberated per square foot of building by a complete burn out of the contents and the combustible parts of the building.

The fire load in a building, or individual sections of it, its position in relation to the boundaries of the site it occupies, and its proximity to other buildings are all taken into acount in assessing the fire grading of the building. In this context the fire grading is the period of time during which a fire is to be contained within a building, or compartment of it, by virtue of the structure and the other components continuing their normal function.

In brief, if a proposed building is awarded a one-hour fire grading then the materials used to fire-protect the structural steelwork must provide at least a one-hour period of fire resistance when fire tested in accordance with BS. 476.

The L.C.C. Building By-Laws and the Model Building Byelaws of the Ministry of Housing and Local Government and Department of Health for Scotland each require the following fire gradings for buildings, ½ hour, 1, 2 or 4 hours depending on the circumstances outlined above.

To return to the main subject, having decided on the form the fire protection was to take, with due regard to the appearance of the building, it was necessary to determine the standard of fire resistance in order to maintain the validity of subsequent cost comparisons.

Although building byelaws acknowledge that 1 in. thickness of concrete suitably reinforced will impart 1 hour fire protection to beams and columns this is not a practicable working thickness. What is more, when designing steelwork to BS 449, which is acceptable to most local authorities, calculations for stresses in beams and columns taking advantage of a reinforced concrete casing are only valid if "the surface and edges of the flanges have a concrete cover of not less than 2 in."

This automatically imparts 2-hour fire protection. Hence the lightweight fire protection had to be able to provide an identical period of fire resistance.

A comparison of unit costs showed beyond doubt that the cheapest lightweight fire protection available, giving a 2-hour resistance, was a hollow casing of vermiculite/gypsum plaster on metal lathing wrapped around the beam or column.

The proportions of vermiculite to gypsum needed are 1½ in. volumes of vermiculite—Grade 2 and 1 volume of retarded hemi-hydrate plaster (BS 1191. Class B) and there must be a 1 in. thickness measured from the face of the metal lath irrespective of the plaster squeezed through the mesh in forming a key.

The Economics of Lightweight Fire Protection

The percentage cost of vermiculite/gypsum plaster, and sheet asbestos casings in relation to the cost of concrete casings is tabulated in Fig. 1 which also includes as a matter of interest the relative cost of a suspended ceiling type of fire protection.

The plaster casing is ready to receive decoration and the cost of a concrete casing therefore included the cost of plastering it, so that they were common in this

Table showing variation of unit first cost of various types of 2-hour structural fire protection

Unit of Measurement	*2″ Concrete casing*	*Vermiculite Gypsum plaster*	*Sheet Asbestos*	*Suspended Ceiling*
Per lineal foot of beam ready for decoration	100	62·5	114·0	Not applicable
Per superficial foot of floor area with ceilings plastered ready for decoration	100	74·0	109·0	96·0

Each comparison has been made on the basis that the unit cost based on a concrete casing is 100.

Fig. 1

Item	SCHEME 1 2″ concrete casings		SCHEME 2 1″ vermiculite/gypsum plaster casings		
	Estimated cost	*Price per cu. ft. of building*	*Estimated cost*	*Price per cu. ft. of building*	*Per cent of Scheme 1*
FOUNDATIONS					
a) 2 tons per sq. ft.	£ 398	1 d	£ 328	$\frac{3}{4}$d	82
b) 4 tons per sq. ft.	£ 221	$\frac{1}{2}$d	£ 186	$\frac{1}{2}$d	84
c) Piles	£ 714	2 d	£ 633	1$\frac{1}{2}$d	89
SUPERSTRUCTURE	£5,571	1/2$\frac{1}{8}$d	£5,135	1/1 d	92·2
COMBINED FOUNDATION AND SUPERSTRUCTURE					
a) 2 tons per sq. ft.	£5,969	1/3$\frac{1}{8}$d	£5,463	1/1$\frac{7}{8}$d	91·5
b) 4 tons per sq. ft.	£5,792	1/2$\frac{3}{4}$d	£5,321	1/1$\frac{1}{2}$d	91·9
c) Piles	£6,285	1/4 d	£5,768	1/2$\frac{3}{4}$d	91·8

The price per cubic foot is correct to the nearest $\frac{1}{8}$d. in each case.

Fig. 2.

respect. The sheet asbestos casing is likewise not plastered.

The beams in question were 10 in. × 4$\frac{1}{2}$ in. R.S.J.s. typical secondary beams from a hypothetical building. If larger beams are cased with vermiculite/gypsum plaster the comparison with concrete will be even more favourable. The reason for this will be explained later.

These figures do not give a reliable guide to the overall economy of steel framed multistorey buildings embodying lightweight fire protection.

This has been evaluated by considering a typical 16 ft. bay of a ten-storey building. The four longitudinal rows of columns in the building were at 18 ft. centres, giving a building approximately 55 ft. 6 in. overall outside walls. The flat roof was designed for a superimposed load of 30 lb. per sq. ft. and the suspended floors 40 lb. per sq. ft. plus a nominal allowance of 20 lb. per sq. foot for partitions.

The building had a two-hour fire grading and generally complied with the provisions of the Model Byelaws.

The steel frame was designed initially in accordance with the recommendations in BS 449 : 1948—this being the Standard in use at that time. The first scheme was based on concrete casings taking every advantage of them particularly in the design of columns. The second scheme was based on the exclusive use of hollow vermiculite gypsum plaster casings to beams and columns.

Three different foundations were considered and evaluated in each scheme.

In order to price the work, details were prepared including floor and wall construction to scales of $\frac{1}{4}$ in. and $\frac{1}{2}$ in. to the foot, and Bills of Quantities were drawn up in accordance with the Standard Method of Measurement for Building Work. These were checked and priced at the rates prevailing at the time. The cost of the floors, finishes, exterior cladding and everything that is irrelevant to the actual cost of structural fire protection had been omitted.

Differences in cost have been added where appropriate ; for example, with plaster casings, owing to the omission of the concrete casing on beams the slab shuttering in a rectangle bounded by two main beams and two internal secondary beams is increased by 4 in. in each direction. This has been allowed for in the costs against Superstructure. For the purpose of showing the cost per cubic foot, the cube of the building was calculated in accordance with the rules laid down by the Royal Institute of British Architects.

The results of the investigation into costs are tabulated in Fig. 2.

The relative cost of piling for Scheme 1 and Scheme 2 may be compared, but it is not strictly correct to compare the cost of a piled foundation with the others tabulated. The cost of piles could vary from site to site depending on circumstances having nothing to do with the type of fire protection employed in the building above.

The most significant factors to emerge at this stage were the reduction of 16 per cent to 18 per cent in foundation costs and of 7.8 per cent off the costs of the superstructure fire protected completely, and ready for decoration.

During the progress of this work, the British Standards Institution published BS 449 : 1959 which will henceforth be the Standard referred to for the design of the great majority of multistorey steel framed buildings in this country.

It contained two items of special significance which were promptly taken into account in a second study of costs. Firstly, empirical rules were introduced which enable the structural engineering designer to arrange a column, still with a 2 in. concrete casing, so that a substantial portion of the axial load on the column is carried to the foundation by the concrete casing itself.

Secondly, it referred to the conditions in which the frictional resistance alone between the top flange of an R.S.J. and the floor slab it supported would be sufficient to provide adequate lateral restraint to that joist. These conditions can be complied with in practice more often than not, and so the main structural asset of a concrete casing, monolithic with the structural floor, loses its value almost completely.

The hypothetical building used to evaluate the effect of concrete casings and vermiculite gypsum plaster was redesigned with composite fire protection; with concrete column casing in the dual role of fire protection for the steel joist and a structural member, and with vermiculite/gypsum plaster on the beams.

Although the maximum working stresses in mild steel to BS 15 have been raised from 10.0 to 10.50 tons per sq. in. and the data in BS 449 calculated accordingly, the stresses in the third example were related to a maximum of 10 tons per sq. in. to keep it in line with the earlier work. Likewise, although the third design post-dated the other two, similar rates for the measured items were used in the evaluation of costs. They are tabulated in Fig. 3 as a percentage of the costs for Scheme 1, mainly to avoid repetition.

These figures are expressed as a percentage of the cost of concrete casings.

Item	*Concrete*	*Vermiculite*	*Vermiculite/Concrete*
FOUNDATIONS:			
2 tons/sq. ft.	100	82	93·7
4 tons/sq. ft.	100	84	95·9
35 ton piles	100	89	94 1
SUPERSTRUCTURE	100	92·2	85 0
COMBINED FOUNDATION AND SUPERSTRUCTURE:			
2 tons/sq. ft.	100	91·5	85·6
4 tons/sq. ft.	100	91·9	85·5
35 ton piles	100	91·8	86·1

Fig. 3.

The foundation costs in Scheme 3 are greater than in Scheme 2 due to the increased dead weight of the column casings, but they are lower than in Scheme 1 mainly due to the reduction in dead weight of the beam casing and partly to the slight reduction in the dead weight of the column casings which of course are smaller.

The most remarkable result is the reduction of the cost of the superstructure in Scheme 3. It is fully fire protected and ready for decoration, and it is 15 per cent cheaper than a corresponding superstructure with conventional plastered concrete casings.

It has been generally accepted in recent years that a reinforced concrete multistorey building frame is between 15 and 20 per cent cheaper than a corresponding steel frame complete with its concrete casings for fire protection.

This difference is accounted for, not only by the cost of the labour and materials which go into the casings, it is also due to the contract time consumed in the process of forming them. It is not uncommon for three or four storeys in a modern tall building to be neutralised for any other trade owing to the presence of props or the erection or striking of formwork from the sides and soffites of beam casings.

The introduction of vermiculite/gypsum plaster on metal lathing leads to a fundamental change in the building programme.

The task of forming fire protection is transferred from the carpenter, the steel fixer and the concretor, working in the open, to the plasterer working inside a weathertight building.

If the process of forming thousands of lineal feet of concrete beam casing can be eliminated, the interval between completing the steelwork and asphalting the roof can be substantially reduced; and for the same reason the other trades can all follow up more promptly. It is true that a substantial amount of metal lathing has to be fixed as a base for the plaster but the increase in the amount of actual plastering work is very small indeed.

The analysis of cost described in this paper did not attempt to evaluate these factors although they must reflect to the credit of lightweight fire protection.

Vermiculite/Gypsum Plaster and Concrete

The combination of vermiculite and gypsum as a plastering medium appears to enhance one common characteristic, namely remarkable adhesion, particularly to concrete. The author knows of no explanation for this phenomenon but it has been convincingly demonstrated in a series of standard fire tests conducted by the Joint Fire Research Organisation of the Department of Scientific and Industrial Research and the Fire Offices Committee. Solid reinforced concrete slabs with varying thicknesses of vermiculite gypsum plaster on their soffites have been tested with the results tabulated in Fig. 4.

Materials	*Minimum thicknesses (inches) to give following periods*							
	4-hour period							
Concrete		3½	4	5	6	7	8	9
Plaster		1	¾	⅜	Nil	Nil	Nil	Nil
	3-hour period							
Concrete		3½	4	5	6	7	8	9
Plaster		¾	½	¼	Nil	Nil	Nil	Nil
	2-hour period							
Concrete	2	3½	4	5	6	7	8	9
Plaster	1	⅜	¼	Nil	Nil	Nil	Nil	Nil
	1-hour period							
Concrete	2	3½	4	5	6	7	8	9
Plaster	½	¼	Nil	Nil	Nil	Nil	Nil	Nil

These ratings are assessments by the D.S.I.R. Fire Research Organisation, based on their own programme of tests.

Fig. 4.

The L.C.C. By-Laws and the Model Byelaws each schedule 4 in., 5 in. and 6 in. concrete floors where 1, 2 and 4 hours respectively, is the period of fire

resistance required. These thicknesses have to be provided, irrespective of structural requirements.

Now it is permissible to introduce a combination of reinforced concrete and vermiculite/gypsum plaster. The Author has in fact done so in two recent contracts. Where a 4-hour fire grading applied, necessitating a 6 in. slab, which, with its conventional plastered soffite would have weighed some 80 lb/sq. ft. it was possible to use a 5 in. slab with a $\frac{5}{8}$ in. vermiculite/gypsum plaster soffite weighing 64 lb/sq. ft. a saving of 20 per cent. Where a 4 in. structural slab would suffice in such circumstances the saving in dead weight amounts to 32 per cent.

Vermiculite gypsum plaster on the beams and on the soffites of the floors has the valuable advantage that the fire protective membrane is continuous over the whole area it has to protect. There is no question of jointing between varying fire protection materials.

Design Data and a Few Words of Advice

It would be idle to pretend that the technique of plastering to give fire protection does not require some extra consideration by the engineer and those he has to advise professionally.

For example the proportioning of gypsum and vermiculite assume much the same kind of significance as, say, the water/cement ratio in concrete manufacture. Variation of the vermiculite/gypsum ratio can be detrimental to the fire resistance. The Technical Committee of the National Federation of Plastering Contractors has endorsed the advice to use factory made pre-mixed plasters thereby guaranteeing the proportions exactly. The trade is known to welcome the idea for a number of other reasons and the material is not in short supply.

It is of the utmost importance to ensure that if 1 in. minimum of plaster is specified for 2-hour fire protection then 1 in. minimum is provided. Metal lathing systems have been devised which incorporate built-in metal guides for the plasterer, which incidentally protect external corners of finished work. More to the point, they give a ready-made means of ensuring that 1 in. of plaster is a physical possibility before plastering commences.

The metal lathing is mass produced and the cheapest component of the lightweight fire protection; the corner beads although mass produced call for considerable precision in their manufacture, and care in their transport to the site. Thus they are relatively expensive even though their cost is measured in pence per lineal foot. This accounts for the earlier statement to the effect that on beams larger than 10 in. × $4\frac{1}{2}$ in. the economies of this form of lightweight fire protection will be seen to better advantage. Whatever the size of beam the cost of the corner beads is constant.

In buildings where hollow casings on the columns are an advantage, care must be taken to ensure that the casing is sealed at each floor level by the structural slab or by some other means, to avoid a flue action when the building catches fire.

Where it is more advantageous to employ load bearing reinforced concrete casings it should be kept in mind that the concrete must attain a works strength not less than 3000 lb/sq. in. at 28 days when tested in accordance with BS 1881 "Methods for Testing Concrete" Part 7 and Part 8, a recommendation in BS 449 : 1959 which did not appear in the earlier British Standard. Until July 1959 the concrete casing on a steel stanchion could only be assumed to increase the stiffness of the column about its weaker axis. When this assumption was made the responsibility for the theoretical load carrying capacity of the column was divided between the steelwork contractor and the general contractor. In designs to the new BS 449 it is possible for the concrete casing to carry up to one-third of the total load on the combined section and the general contractor's share of the divided responsibility is greatly increased. The problems here are self-evident. They are not usually insuperable but they should be borne in mind by the structural engineer appreciating a particular problem.

Vermiculite/gypsum plasters have a slight resilience and they are not liable to crack with the normal deflexion of beams and slabs.

The set and dried density of a $1\frac{1}{2}:1$ mix of vermiculite gypsum plaster may be taken as 42 lb. per cubic foot or 3.5 lb. per sq. ft. per one inch thickness.

The engineering designer should include an allowance for the metal lathing and the plaster which squeezes through the mesh to form a key; it has been found that a total allowance of 5 lb/sq. ft. of finished plaster casing caters for this.

It is quite common in buildings which have a general 1- or 2-hour fire grading, to find that in places, 4-hour fire protection is required. Typical, in London for example, is the basement or sub-basement car park which is a planning requirement in many buildings; and depending on the type of installation, the heating chamber.

Vermiculite gypsum plaster will serve as a 4-hour protection to steelwork in such places. $2\frac{1}{4}$ in. of $1\frac{1}{2}:1$ mix is required and as an additional safeguard this thickness of plaster must be reinforced by the introduction of a 1 in. galvanised woven wire mesh $\frac{1}{2}$ in. beneath the finished surface of the plaster casing.

A 1-hour fire protection can be provided by $\frac{1}{2}$ in. of $1\frac{1}{2}:1$ plaster applied to the metal lath in the usual way.

The thermal transmission of the $1\frac{1}{2}:1$ mix is 1.30 B.T.U/sq. ft. 1 in. thickness/1°F difference in temperature.

Lightweight Fire Protection in the United States

Although there is no direct way of comparing the cost of building work in America with similar work in this country the results of American experience in this field are not without interest.

The periods of fire resistance required, the fire grading of buildings, and the stringency of American fire testing are consistent with British practice.

At the beginning of 1958 it was recognised that, in America, a reinforced concrete frame in a multistorey building was cheaper than a steel frame with dense concrete casings. Circulars issued to their Regional Directors by the Public Housing Administration in Washington D.C. in July 1958, encouraged them to consider the economics of steel framed buildings with lath and plaster fire protection. This action was taken following the receipt of competitive tenders for a project in Illinois, and a conference of the P.H.A. with members of the steel and plastering industries. During the conference, the Illinois project and three others were reviewed which all showed savings effected by steelwork with lath and plaster fire protection, compared with reinforced concrete. In addition, cost estimates of a newly completed 12-storey office building prepared by a professional estimating service were considered. The cost estimates of the four projects in different cities supported the evidence of the competitive tenders for the Illinois project.

The figures published in connection with each of these are repeated on the next page.

	Frame cost per sq. ft. of floor area, in dollars		*Steel frame saving %*
	Fireproofed steel	*Reinforced concrete*	
Typical 12-storey office building, Chicago	2·73	3·65	25·2
48-storey apartment building, New York	2·50	2·79	10·4
2-storey hospital, Long Island	2·59	2·95	12·2
12-storey apartment building, New York	2·34	3·21	27·0

Fig. 5.

The tenders for the Illinois project which consisted of three 8-storey blocks of flats were 5,236,752 dollars based on a reinforced concrete design and 4,957,710 dollars based on the steel frame lath and plaster design, a saving of 279,042 dollars, or just over 5.3 per cent. The analysis of structural cost alone is not available, but from other American data it appears that a saving of 5.3 per cent on overall cost represents 20 to 25 per cent saving on the frame. It was emphasised that both designs were based on an identical appearance of finished building with identical live floor loading, ceiling heights, partition layouts and both with 2-hour fire grading.

Conclusion

There is no room for doubt that vermiculite and gypsum plaster will make steel framed multistorey buildings cheaper than ever before, both on account of its light weight and because it provides an adequate fire protection to an uncased beam deriving adequate lateral restraint from the frictional resistance of the slab alone.

It is generally conceded that a fully productive steel industry is important to the national economy and any constructional technique which encourages the wider use of structural steel warrants the most serious considerations, especially when the net result is cheaper buildings.

Revolutionary techniques do not always live up to the hopes of their sponsors, but there is nothing revolutionary in the technique of plastering nor in the idea of using it for fire protection.

Book Reviews

Structural Design for Dynamic Loads, by C. H. Norris, R. J. Hansen, M. J. Holley, J. M. Biggs, S. Namyet, and J. K. Minami. (New York and London : McGraw-Hill, 1959). 9 in. × 6 in. 453 + xiv pp. 97/-.

This volume, compiled from lecture notes prepared for a special two-week summer programme held in 1956 at the Massachusetts Institute of Technology, is not a textbook or reference book, but is intended as a survey of the field of structural design for dynamic loading.

The twenty chapters in the book have been divided into four parts, as follows. The first part on the behaviour of materials under dynamic loading contains two chapters, one on the behaviour of steel and steel elements, and the other containing a similar discussion on concrete and concrete structural components. The second part, on the calculation of response of structural systems to dynamic loading, contains five chapters, the first on the response of a simple one-mass system to typical dynamic loadings and the following two chapters dealing with the application to concentrated-mass systems of any number of degrees of freedom and to distributed mass systems. Chapter six comments on the more important theoretical and practical limitations to the theory presented in the previous two chapters, and the last chapter in this section gives several approximate methods for computing dynamic response in typical examples. The two chapters in the third part of the volume deal with numerical integration methods and their application to dynamic-response calculations, and to the application of analogue and digital computers

The remainder of the book is devoted to the application of structural design and analysis to specific cases involving dynamic loading, and particularly to blast-resistant design, on which there are six chapters, containing material taken from a design manual prepared for the U.S. Army. Two chapters follow, summarising earthquake resistant design methods and practice, and current American and Japanese codes, and chapters on the vibration of girders under moving traffic loads and the dynamic effects of wind loads complete the volume. Each chapter concludes with a useful bibliography giving suggestions for further study.

This valuable publication, which is well illustrated throughout, will be of particular interest to engineers studying blast-resistant and earthquake resistant design and construction problems.

Proceedings of the First Japan Congress on Testing Materials. (Kyoto, Japan : The Japan Society for Testing Materials, 1958.) 11 in. × 8½ in. 179 pp. & Appendix.

The first Japan Congress on Testing Materials was held in Tokio in October 1957 under the auspices of the National Committee of Testing Material of the Science Council of Japan, thirteen societies taking part.

Seventy-eight papers were presented at the Congress, and fifty-four of these are published in the Proceedings. Of these, thirty-six papers deal with metals, nine with non-metallic materials, and nine with miscellaneous subjects. Papers in the non-metallic section include a testing method on the shape of crushed stone aggregates for concrete, a method for making the concrete cylindrical specimens and testing methods on mortar and concrete crack due to hardening and drying shrinkage.

The volume also contains an appendix on the present industrial situation in Japan.

Railways into Roadways ? —are Railways Doomed ?, (London : Morgan Brothers (Publishers) Ltd, 1959.) 97 + vi pp. 6/6d.

A leader in *The Engineer* of January 31, 1958 under the title " Railways into Roadways " discussed the revolutionary ideas put forward by Brigadier T. I. Lloyd, C.B.E., D.S.O., M.C., at the first conference of the Railway Conversion League. This leading article led to a lengthy, interesting and sometimes vehement correspondence, which is reproduced in this booklet, together with three leading articles on the subject and a foreword. These articles and the correspondence are set out in chronological order.

The Structural Engineer in the Field of Atomic Energy*

by T. C. Waters, M.I.Struct.E., (Delegate Member of Council)

Chief Structural Engineer, United Kingdom Atomic Energy Authority (Industrial Group)

Synopsis

1946 saw the birth of Atomic Energy as a new industry. The Author will attempt to describe the part played by the structural engineer during the subsequent impressive years in which he, as a member of a team, has been involved in the design and construction of the buildings which house the nuclear research, prototype, and power reactors, and also their associated plant and equipment. He will briefly discuss the more relevant aspects of some of the process buildings, reactor buildings, of biological shielding for reactors, and of containment buildings.

1957 saw the United Kingdom launch its nuclear power programme. He will show how caution and courage have been fellow travellers with the structural engineer during this pioneering period, and will suggest some fields of research and development in which the future contribution of the structural engineer will be most effective.

Introduction

In the spring of 1946 work on the construction of BEPO started in an aircraft hangar on a disused aerodrome at Harwell, and in the spring of 1946 a new and exciting industry was born in the United Kingdom.

The chain of spectacular nuclear scientific and engineering discoveries and achievements which followed in quick succession during the succeeding 10 years leading to the distribution of electricity into the national grid from Reactor No. 1 at Calder Hall has fired the imagination of all who recognise the importance of this new industry to the welfare and well-being of present and future generations.

Controlled fission is now a commonplace term in the field of atomic energy, but behind this simple term lie years of closely knit teamwork between scientist and engineer. In the course of these purposeful and impressive years of research, design, development, and construction, the structural engineer has played his part in the achievements which have paved the way to the successful launching of Britain's nuclear power programme.

In the fields of nuclear research, defence, and power production, enough material already exists for several papers, and indeed a number of papers concerning structural aspects of atomic energy have already been published elsewhere. Such landmarks will be referred to only briefly. It may legitimately be argued that in matters of defence a curtain of secrecy still exists, and as the Author is unable to speak authoritatively in this connection he will confine his thoughts to research and production and to atomic energy's contribution towards peace and plenty.

* *Paper to be read before The Institution of Structural Engineers, at* 11, *Upper Belgrave Street, London, S.W.*1., *on Thursday,* 28*th January* 1960, *at* 6 *p.m.*

It is his intention therefore to make a broad survey of the part played so far by the structural engineer, more especially in the United Kingdom story of the gas cooled graphite moderated reactor, and to consider his continuing contribution in the progressive development of atomic energy. In an attempt to cover such a wide field in the short time at his disposal he must of necessity be guilty of a great deal of over-simplification for which he seeks the reader's forbearance.

Now by far the greatest weight of effort by the structural engineer has been, and is likely to be, in the production of the many and varied conventional buildings which are a necessary feature of atomic and to some extent of many other projects. Such buildings would include administration blocks, surgeries, fire stations, workshops, research and development centres, boiler houses, pump houses, substations, cable, pipe, and services bridges, turbine houses, blower houses, heat exchanger houses, chemical process buildings, laboratories, shielded buildings, decontamination plant and incinerator buildings, storage buildings, fuel element fabrication buildings, active ducts and inactive ducts and the like. These, therefore, should not be overlooked in this paper as some have provided many interesting and indeed challenging problems.

On the other hand, certain aspects of the work of the structural engineer have demanded special consideration such as biological shielding, and perhaps to a lesser extent cooling ponds for irradiated fuels. Novel problems, particularly in connection with containment buildings have presented themselves for early solution and/or decision.

Certain of these problems and techniques arising from atomic energy requirements will be discussed in some detail, particularly where they have exposed gaps in our present fundamental knowledge, calling for further research or study, and references to shortcomings in existing codes or specifications will be made.

The United Kingdom Atomic Energy Programme

Work on the Harwell Atomic Energy Research Establishment was followed immediately by the reopening of and extensions to a disused chemical plant at Springfields for the production of uranium fuels. In 1947 a start was made on the air-cooled graphite moderated pile at Windscale, together with the chemical separation plant for the processing of irradiated material. By the middle of 1950 work had started on the construction of a diffusion plant at Capenhurst for the production of enriched uranium. By mid 1953 the construction of the first of two nuclear power reactors at Calder Hall had been started. 1954 saw the fast breeder reactor project launched at Dounreay which is being developed as a reactor proving ground. At the beginning of 1956 work started at Chapelcross on 4 " Calder Hall " reactors, the first of which went on

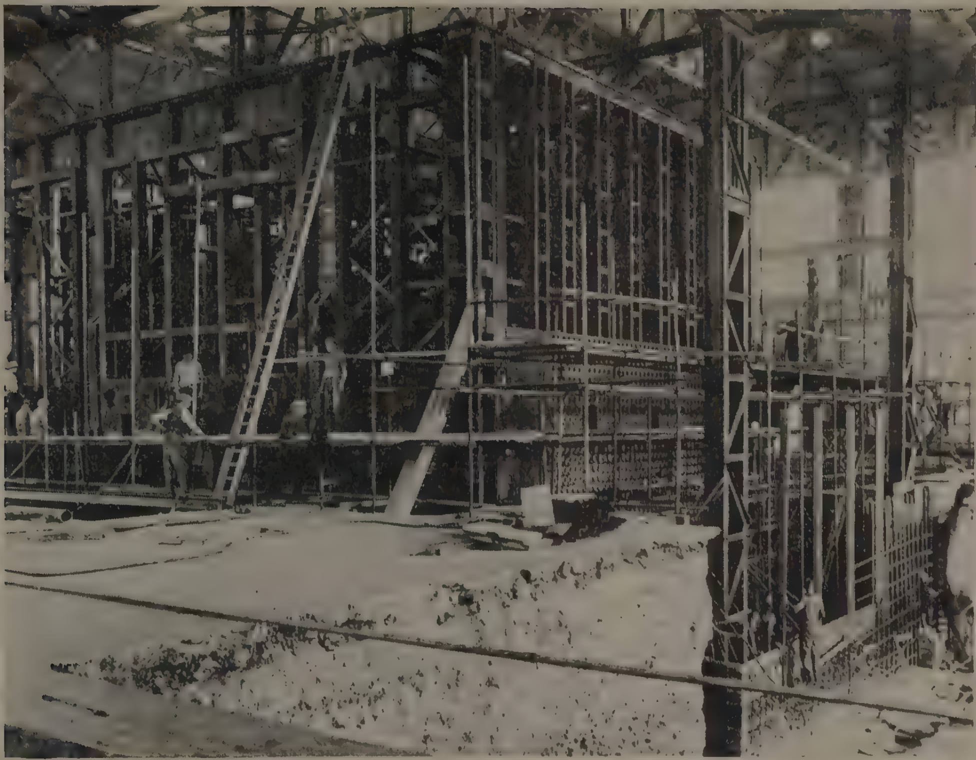

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Fig. 1.—Harwell—BEPO Biological Shield under construction

load in February 1959. In 1956 work was started on a new factory at Springfields to ensure that the increasing demands for uranium fuels in the United Kingdom Nuclear Power Programme would be met. In the spring of 1958 a new Reactor Research Establishment at Winfrith Heath in Dorset was opened up. In October, 1958 work commenced at Windscale on the advanced gas cooled reactor, a possible prototype of the Mark II nuclear power reactor.

The construction of the first two Mark I nuclear power stations for The Central Electricity Generating Board based on Calder Hall design commenced in January 1957, two more were commenced later in the year, a fifth started in the summer of 1959 and a sixth in 1960.

It may be said that the first milestone in the pioneering of atomic energy as an industry was reached on the 17th October, 1956 when Her Majesty the Queen switched current on a commercial scale into the National Grid from Calder Hall, for the scientists' dream of 1946 had within a decade become an engineering reality.

Programming

Feasibility studies for new reactor projects are always accompanied by the production of a master programme and this is governed by three main considerations :

1. The nation's need.
2. The most optimistic assessment of the time needed for the design and provision of the reactor plant and equipment.
3. The most economic means for meeting the earliest date for the reactor to go critical

and the master programme is geared to these.

Once the design study and flow sheets are accepted the master programme becomes the bible for construction and date of "hand-over," and every effort by all members of the teams concerned is concentrated upon meeting the final date.

It will be readily understood that in this, as in other new fields of research and design involving the use of hitherto unused materials, new problems are posed to the nuclear scientist often demanding early answers before the chain of research can be completed. New test rigs may be called for, even new development and research buildings are required, and these "side issues" would demand immediate action as they were logically affecting the main line of the master programme.

Now the total cost of the civil and building work for reactor buildings and process buildings is usually only a small fraction of the total cost of the plant and equipment they house. It may well be as low as $7\frac{1}{2}$ per cent, which means that construction delays may tie up a good deal of capital. The structural engineer is therefore bound to accept the situation in which his contribution must be dovetailed into the project in such a manner that overall economy is achieved, even if it means that an otherwise continuous construction or series of constructions is broken down into intermittent phases with all that this may imply in design and cost. His engineering preferences must sometimes be subordinated to the legitimate needs of the project as a whole. The emphasis is on speed.

Materials of Construction

Mild Steel

It has been clear from the outset that the medium which would best satisfy the main demands made

upon the structural engineer for speed and adaptability was mild steel. This was a material available in quality and quantity, and was capable of being moulded to the varying and sometimes exacting needs of the scientist, even if the effort to obtain it in the right quantity and at the right time sometimes involved a great deal of forward planning and a certain amount of crystal gazing and educated guesswork. It lends itself, when erected as a structure, to late changes of design and detail without necessarily impairing its integrity. Mild steel in its many forms, hot rolled sections, plates and flats, cold formed strip, and tubes have all been used.

Reinforced Concrete

Concrete finds its place in any structural engineering work, and the field of atomic energy is no exception. Quite apart from its employment for work which might be classified under the heading of normality, its use for biological shielding purposes has brought with it an awareness that gaps exist in our knowledge of its characteristics under certain conditions, but this will be discussed later. The use of heavy aggregates has also been adopted for certain shielding purposes.

Special Steels

Special steels have been employed for the containment vessels at Harwell, Dounreay and Windscale, the selection of which arise from the varied requirements of temperature, notch toughness, weldability etc., and a short description of these will be included later under their appropriate headings.

Harwell A.E.R.E.

The first of Britain's large scale experimental reactors BEPO was constructed inside an aircraft hangar, and in order to accommodate it part of the hangar roof was raised by approximately 30 ft. without the use of props. To achieve this, two of the 150 ft. span roof girders carrying " scissor " type trusses were severed, their centre portions were removed, and new steel girders spanning in a transverse direction, carried by adjacent existing girders were provided to support the remaining sections of the roof girders, a high level steel framed structure, and a 5 ton electric overhead crane. The adoption of this scheme enabled foundation work and reinforced concrete construction of the pile shield to proceed at full speed and under cover, thereby saving at least six months in the construction of the reactor. Time was all-important for the race for nuclear power was now on.

From this time the structural engineer has been employed in a continuous and progressive role at Harwell, including the design and construction of administration buildings, blower houses, a cyclotron, a proton synchrotron, hot laboratories, zero energy buildings, etc., and more latterly the 7-Gev Proton synchrotron project.

This last project is of massive proportions, and consists mainly of an injector room, magnet room and an experimental area. The magnet, weighing approximately 7,000 tons lies on an annulus of about 150 ft. diameter, and its foundation must not hog or sink by more than $\pm \frac{1}{4}$ in. across its diameter. The magnet is supported upon a cellular disc foundation about 160 ft. dia. which also carries a central column and eight other columns at 100 ft. dia. circle. These carry two heavy electric cranes, a massive circular roof of 4 ft. 6 in. minimum thickness with earth mounding in addition. The shielding bridge between the magnet room and the experimental area spans 160 ft., is dog legged in plan, 28 ft. wide $\times$ 17 ft. 6 in. deep. It is supported by a pier at the change of direction and at its two abutments. The pier which carries approximately 7,500 tons has a central section of only 1 ft. $\times$ 8 ft. for a height of 2 ft. 6 in. on the plane of the experimental beam.

Windscale

Among the many and varied buildings which have been erected at the Windscale Factory the most interesting and important structures were those which

Atomic Energy Research Est.

Fig. 2.—Harwell—7-Gev Proton Synchrotron under construction

Fig. 3.—Windscale—The Pile Buildings

housed the air cooled graphite moderated production piles which were a development from BEPO. These two buildings are 140 ft. high × 80 ft. wide × approximately 200 ft. long, having main frames at 22 ft. centres supporting a 25 ton electric crane approximately 130 ft. above ground floor level, and capable of placing loads in position on the pile roof with extreme accuracy.

Steel erection procedure was governed by the nature of construction work on the reactor shield, starting at the centre of the building and proceeding towards each end concurrently. Two 10 ton 120 ft. jib Scotch derricks mounted on gabbards 40 ft. high and running on tracks, were employed for this purpose.

Fig. 4.—Capenhurst—Part of Process Building

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Fig. 5.—Calder Hall

Each of the piles is built in a reinforced concrete biological shield approximately 70 ft. long $\times$ 48 ft. wide $\times$ 70 ft. high with walls and roof up to 9 ft. thick. Cooling air is blown through the pile, the warm air being conveyed to atmosphere by a reinforced concrete chimney 40 ft. in diameter, 415 ft. in height with filters provided at the top. The total weight on the foundation is approximately 60,000 tons and is carried on a concrete raft 200 ft. long $\times$ 100 ft. wide $\times$ 10 ft. thick.

The pile buildings, chimneys, blower houses and control rooms form two impressive groups, but now stand as a sombre monument to the pioneers of atomic energy.

The Capenhurst Diffusion Plant

The Process Building

The process building has been fully dealt with elsewhere but it is worthy of a brief reference below.

It is a large single storey steel framed structure with overhead electric cranes and runways for handling electrical and chemical plant and equipment. Inside, and covering over 80 per cent of the floor area, the plant is housed in rows of steel framed insulated boxes or cells, slightly pressurised, and inside the cells the stages are arranged in groups varying in size according to the position they occupy in the diffusion process. The building was erected in four phases roughly equal in size, each phase being brought into operation progressively so that phase 1 was in production while phase 2 was under construction. It now has 24 bays, and together with its associated workshops covers an area of over 30 acres.

Superstructure

Design conditions for the building superstructure included amongst many others the need to limit lateral and vertical movement of the roof to $1\frac{1}{2}$ in This requirement meant that both the roof and its supports had first to be designed and then checked for deformations, to ensure that the specified movements were not exceeded.

Because of the anticipated eventual size of the building, and in order to create a balance between temperature and wind movements and stresses, expansion joints were provided across the building and along the building, breaking it down into units approximately 410 ft. $\times$ 180 ft., $\times$ 46 ft. high to eaves, embracing three spans of 117 ft. and three corridors of 19 ft. 6 in. in width, and 8/22 ft. 6 in. bays in length. Spans of up to 150 ft. were later used over the cell areas to accommodate larger arrangements of cells.

Tubular construction was adopted for the roof trusses in some of the bays. Hot finished tubes were used having a guaranteed yield of 15 tons/sq. in. and an effective saving of up to 33 per cent in weight of steel was achieved compared with trusses made from hot rolled sections.

The Cells

The steel framed cells vary in size from 108 ft. $\times$ 43 ft. $\times$ 20 ft. high, down to 8 ft. 6 in. $\times$ 7 ft. 6 ins. $\times$ 17 ft. high, according to the position they occupy in the rectifying process. The air in the cells is dried and the working temperature is kept at about 140° F.

In general, the main framework for the cells consists of rolled steel joists, but secondary members carrying the cladding were made from cold rolled sections in 8 gauge mild steel. The use of this light gauge material effected considerable savings in weight of steel but introduced a number of fresh techniques in the shops on the site. Once again accuracy was of prime importance, and fabrication and erection tolerances were carefully prescribed.

Cell Foundations

The cell foundations were in clay, and sustained high temperature conditions within the cells made a consequential heat transfer to the supporting clay below the cell floors inevitable. Careful consideration was therefore given to the problem of retaining the natural water content of the clay. This was only slightly higher than the shrinkage limit. The main site drainage was

therefore laid in advance of any work in the cell area and as this area was stripped it was covered and sealed with a layer of P.B.S. which was laid to natural falls into the main drains. This enabled work to proceed rapidly in the English climate with a minimum volumetric change in the clay, to minimise shrinkage and subsequent movement of the cell slabs which were 110 ft. long × 90 ft. wide. Every effort to maintain initial accuracy in levels and to avoid subsequent differential settlement was made, because the stage units which were built into the process system were interchangeable, and were flexible only within very fine tolerances.

Calder Hall

The Reactor Buildings

The reactor is graphite moderated and gas cooled under pressure. The core and its graphite moderator is contained in a cylindrical pressure vessel supported upon "A" frames which rest on grillages bolted to the main foundation raft. Emerging from the top dome of the vessel and passing through the roof of the biological shield are charge and discharge tubes through which fuel elements are lowered into and removed from the reactor.

Cool carbon dioxide gas enters the pressure vessel at the bottom through four 4 ft. 6in. dia. steel ducts, passes through the reactor core, and hot gas is carried away at the top through four 4 ft. 6 in. steel ducts to the tops of four heat exchangers located one on each corner of the reactor building.

The Biological Shield

Surrounding the pressure vessel is the concrete biological shield, the inner face of which is protected by a 6 in. thick steel thermal shield. Induced draught cooling air is passed through a 6 in. space between the thermal shield and the concrete face of the biological shield, and outlet air is extracted through two steel stacks supported on the roof of the reactor building.

The biological shield is octagon in plan, 46 ft. across flats, 89 ft. high, with walls 7 ft. thick, and roof 8 ft. thick. It is supported upon a raft 11 ft. thick × 130 ft. long × 104 ft. wide which carries a total load of approximately 31,500 tons. The concrete is made from Whinstone aggregate giving a minimum dry density of 150 lb/cu. ft. To achieve this dry density, a minimum density of 153 lb/cu. ft. at seven days was specified. The concrete shield was cast generally in 4 ft. 6 in. lifts to minimise the effect of heat of hydration.

Each of the four heat exchangers was supported on its own foundation adjacent to the reactor raft. Fine limits on differential settlement between reactor and heat exchangers were laid down because each supported the pressurised coolant gas system passing between them. Care was therefore exercised at all times during construction to avoid tilting due to eccentricities between applied loads and the ground reactions, and the sealing of the coolant gas circuit was delayed as long as possible in the site programme to minimise the effects of differential settlement between them.

The Turbine House

The turbine house derives its interest not so much from its size as from its concept, for its general lines are light and its members slender. Its sides are clad with patent glazing and asbestos sheeting, and its roof with metal decking. It contrasts well with the turbine house of a conventional U.K. thermal power station and may well set a new standard for the nuclear power age.

The building consists of a main hall approximately 60 ft. high × 80 ft. span × 240 ft. long with a 60 ton overhead electric crane. The steam side on the one hand and the electrics and control side on the other are both approximately 40 ft. high. In design it was largely box braced. The main columns were fixed at foundation level and the tops propped at roof level by horizontal girders which transmitted lateral forces to the vertical bracing systems in the gable ends. The columns were also propped at gantry rail level by horizontal girders in the roofs of the steam and control sides, transmitting lateral loads to intermediate and gable vertical bracings. A series of vertical bracings dealt with the wind and crane forces in the longitudinal direction.

The main roof girders, varying in depth from 18 in. at the eaves to 40 in. at the centre and having tapered flanges, were delivered in two halves, welded together at site on the ground and lifted in one piece.

Erection of the framework was by means of one 15 ton 120 ft. jib Scotch derrick on tracks running along the steam side, with a mobile crane handling the steel for the control block.

Cooling Ponds

Cooling ponds for irradiated fuel elements have been built at Windscale and they are also a feature of all C.E.A. nuclear power stations.

The pond recently constructed at Windscale to handle cartridges from Calder and Chapelcross has general dimensions of approximately 200 ft. × 50 ft. between walls, sub-divided into separate compartments, and contains 18 ft. head of water with a free board of 3 ft. In the inlet section, concrete with a seven day density of 150 lb. per cu. ft. was specified. In general, wall thicknesses were governed by shielding requirements and were 2 ft. 8 in. thick.

Because of the remote handling problems of the "coffins" weighing nearly 50 tons, tolerances and clearances in concrete dimensions and levels were specified to $\pm\frac{1}{8}$ in.

Construction and contraction joints were provided with a P.V.C. water stop with a bitumastic seal on the water face, and expansion joints were provided with a premoulded filler in addition.

The floor was designed and constructed as two independent layers with joints staggered, the concrete for both being treated as an impermeable barrier, for the specification called for a tank which was drop tight.

The walls were cast in lengths of 20 ft., with 2 ft. shrinkage gaps and in one pour, to minimise the number of construction joints.

The leakage test laid down for the pond involved slow filling, and the tank being held full for seven days. After this, daily records of the water level were taken and adjusted for evaporation and rainfall. Permissible leakage was limited to $\frac{1}{20}$ in. per day.

Winfrith Atomic Energy Establishment

Work on the atomic energy establishment at Winfrith Heath started in the spring of 1958. Two Zero Energy Halls have already been completed and a third will be started in the spring of 1960. In addition $3\frac{1}{2}$ miles of concrete active and services ducts have been built, together with workshops, laboratories, administration blocks, and all the ancilliary buildings necessary to make it self-contained.

The site, consisting of a thin layer of loose gravel overlying the bagshot beds, and having a 2 ft. water table has provided many interesting foundation problems, for which piling, de-watering, and vibro flotation techniques have been employed at one time or another.

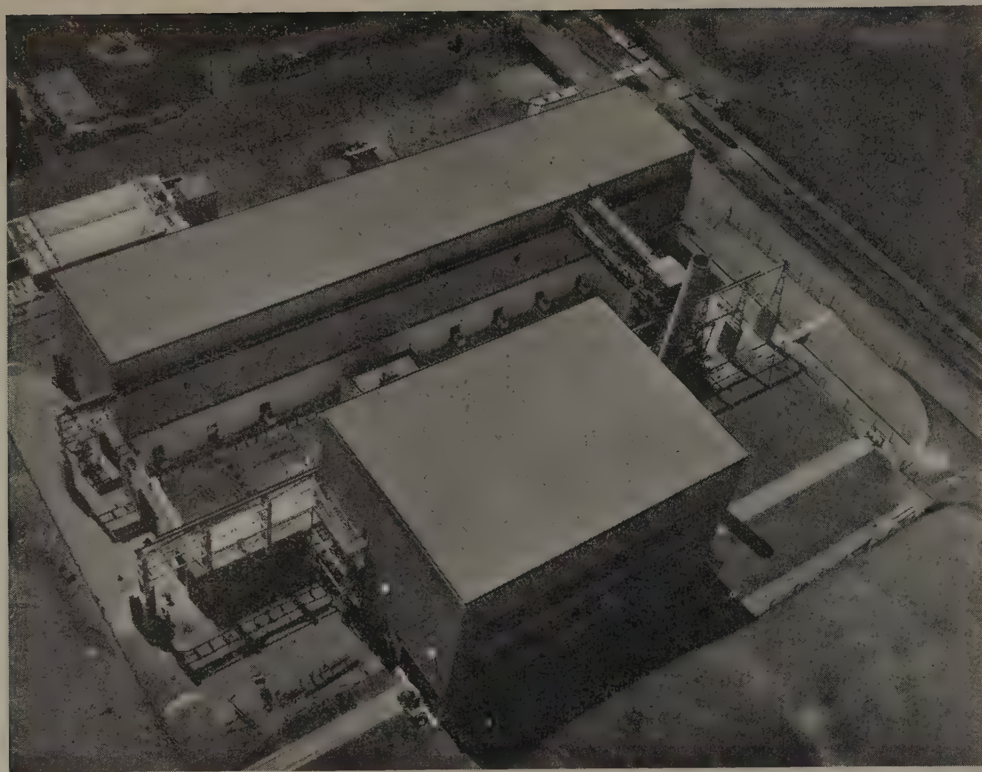

Fig. 6.—Windscale—The Cooling Ponds

Springfields—Second Uranium Production Plant

The production of uranium for use in the early reactors in this country was started in 1947, in an existing war-time chemical defence factory at Springfields, near Preston, Lancs. With modifications and additions this existing factory was used, until it was evident that the increased need for uranium arising from the development of the C.E.A. Nuclear Power Programme, would have made the original plant completely inadequate.

In 1955, therefore, a decision was made to build a new factory on an area within the perimeter fence of the Springfields site. The factory was planned for " line " production, with uranium ore entering at one end, and the finished product in the form of canned fuel elements leaving the plant at the other.

Site clearance and general levelling commenced early in 1956 and this was followed by foundations and steelwork erection.

Most of the buildings are steel framed—the first phase covers a ground area of approximately ten acres—and the job involved the use of some 7,000 tons of structural steel. The speed at which erection was required led to the necessity of employing two steelwork contractors.

Steelwork erection generally was completed by the end of 1957, and the buildings made weathertight by the spring of 1958.

Further work on the site, in the form of extensions to the originally projected buildings, is still proceeding.

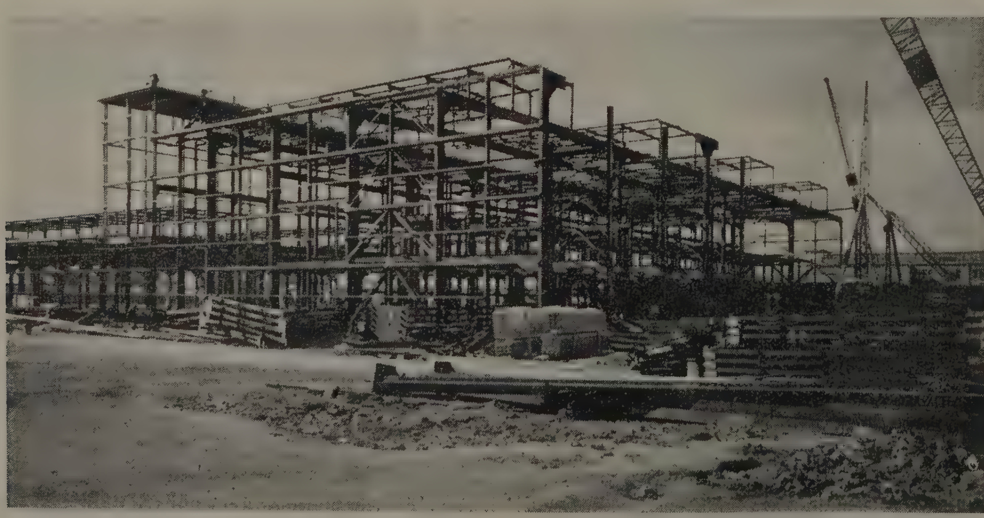

Fig. 7.—Springfields—2nd Uranium Production Plant under construction

Fig. 8.—Berkeley Nuclear Power Station under construction

Dounreay Plutonium Criticality Facility Containment Building (P.C.F.)

The P.C.F. containment building houses a facility for experiments to investigate the safety and characteristics of potential reacting systems. It consists of a steel cylinder 27 ft. dia, 17 ft. high with a top dome and steel plate floor containing a steel lined pit. The thickness of the plate for both the cylinder and the dome is $\frac{1}{2}$ in., but reinforced as necessary for the 8 ft. door. The normal operating conditions are for an internal pressure of 2 lb/sq. in. gauge and an external pressure of 1 lb/sq. in. gauge, this being limited by the introduction of a vacuum relief device introduced into the ventilation system. The incident pressure is 10 lb/sq. in. gauge and the building has been constructed to a leak tightness of 1.0 per cent leakage in 24 hours.

The Advanced Gas Cooled Reactor (A.G.R.)

The A.G.R. now under construction at Windscale may well prove to be the prototype for the United Kingdom Mark II Nuclear Power Reactor. The use of enriched fuels in Beryllium cans, higher reactor operating temperatures and pressures with a corresponding increase in efficiency, makes this reactor an attractive successor to the Calder Hall type.

The structural engineer in his share of the work has been presented with some absorbing problems in the design and construction of the biological shield, which carries not only the reactor and the pressure vessel but also the four heat exchangers, and in addition, all the plant rooms surrounding the reactor.

The shield is 30 ft. inside diameter by approximately 60 ft. high. The lower half of the walls being 9 ft. thick and the upper portion 4 ft. thick. A total load of approximately 23,000 tons including the weight of foundations is carried on a circular disc approximately 77 ft. diameter.

The " pear drop " containment building enclosing the whole of this has a spherical diameter of 135 ft. supported upon an inverted trunkated cone, which sits upon a concrete foundation designed as a dished end to meet the pressure conditions laid down for the containment building. A gas-tight steel plate floor completes the seal.

In order to eliminate serious negative pressures in the building, vacuum relief valves are being employed to operate at $\frac{1}{4}$ lb/sq. in. gauge, and although an internal pressure build-up of 10 lb/sq. in. gauge could arise in an emergency, this can safely be resisted by a plate thickness of $\frac{1}{2}$ in. which is indeed the thickness of the 135 ft. dia. spherical dome.

The C.E.A. Nuclear Power Programme

The C.E.A. Nuclear Power Programme has been launched and a number of " Mark I " Stations based on Calder Hall, but considerably larger and more efficient, are now being built.

Stations at Berkeley and Bradwell are now in an advanced stage of construction, with Hinkley Point and Hunterston following in step behind them. Work on a further station at Trawsfynydd commenced in the summer of 1959, and a start on a sixth station at Dungeness is expected early in 1960. This is part of the programme to get an installed capacity of 5,000 MW from Nuclear Power Stations by 1966.

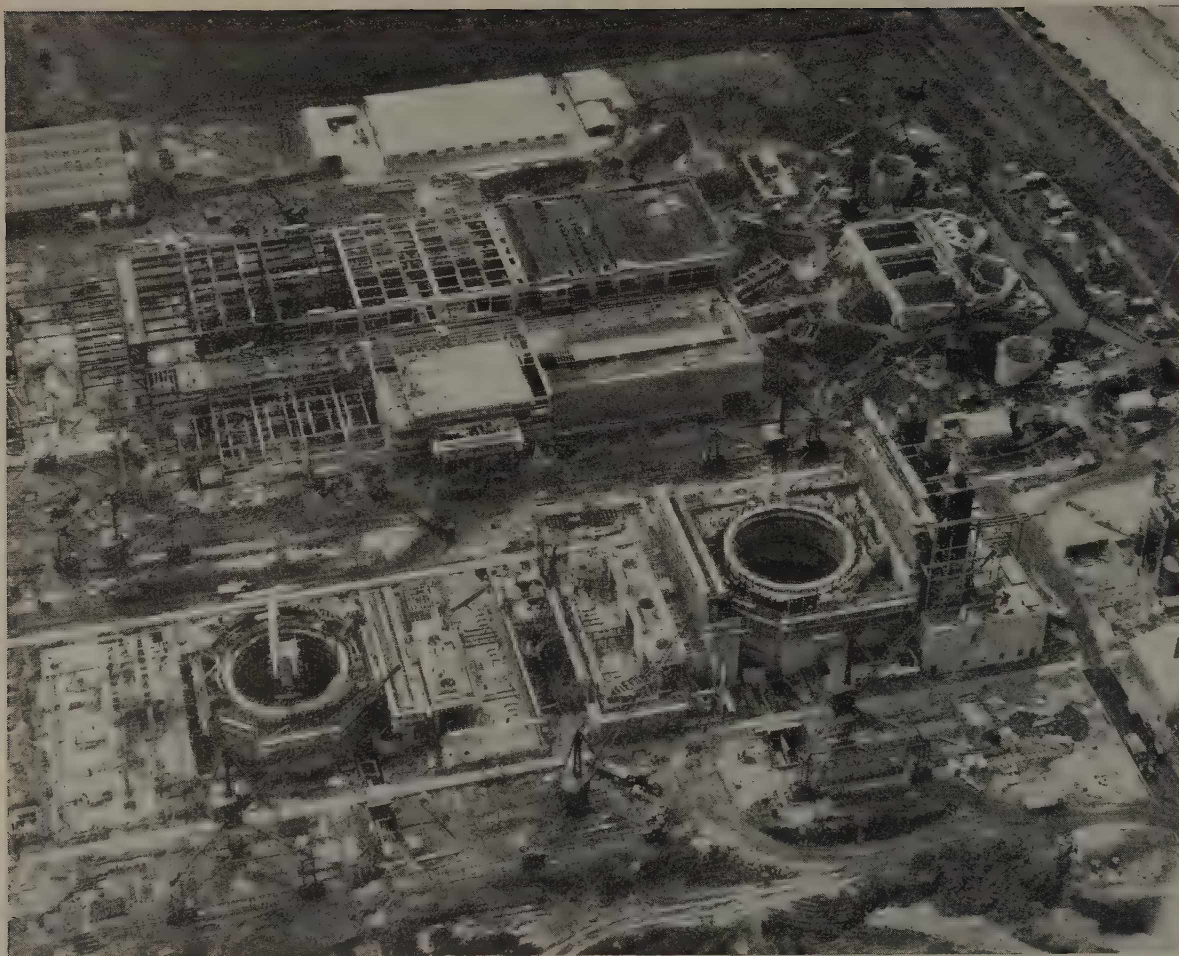

Fig. 9.—Bradwell Nuclear Power Station under construction

Biological Shield Design

The biological shield acts as a physical barrier to protect personnel from harmful radiations released from the reactor core. These radiations consist of alpha particles, beta particles and neutrons, and of these the alpha and beta particles are normally absorbed in the core of the reactor. The neutrons, however, have very great penetrating powers and in the course of their absorption in the shield, emit gamma rays which in turn require further shielding. The neutrons and gamma rays can only be attenuated, and shielding can do no more than to reduce the amount of these radiations to a specified level at the external face. Neutrons fall into two classes, fast and thermal. In a reinforced concrete shield fast neutrons are slowed down to thermal speeds by collision with the hydrogen nuclei present in the water of hydration. Gamma rays are absorbed more readily by the heavier nuclei and in general it is necessary only to provide a sufficient mass of shield material to deal with these.

Heat is generated in various ways within the shielding material. When a fast neutron is slowed down by scattering, energy which appears as heat is imparted to the nuclei of the shield. When a thermal neutron is captured a gamma ray is liberated, the absorption of which also releases energy in the form of heat.

The amount of heat and the distance within the shield at which it is liberated depends upon the type of radiation being absorbed and also the material forming the shield. A steel shield, for instance, is almost transparent to fast neutrons which thus produce no heat during their passage. Thermal neutrons passing through steel, and their associated capture gammas would, however, be absorbed with considerable heat generation.

The elevated temperature conditions arising within the shield are therefore primarily due to two reasons :—

1. Heat generated in the core and not dissipated by the coolant systems. This takes the form of a straight line temperature gradient through walls, roof, and floor.
2. Heat generated by neutron attenuation or capture. This takes the approximate form of a parabola with its apex about 18 in. from the inside face of the shield.

In the structural design of the shield this latter condition has been idealised by replacing the parabolic curve by an equivalent straight line in which the area under the line equals that under the curve and so that the moments about the internal face are the same. This assumption ensures that the overall effect of the bending and axial forces due to temperature are unchanged, but it leads to a possible underestimate of the maximum stress.

The use of a steel thermal shield at Calder reduced the apex of the neutron heating parabola to approximately 11° F. and the approximations referred to are logically permissible. If the thermal shield is omitted

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Fig. 10.—Hinkley Point Nuclear Power Station under construction

in future reactors, and because of its cost this omission must be considered, this aspect of design would need more careful analysis as the neutron heating effect would be large.

Concrete, as a material for biological shielding, has been found to be cheap and reasonably satisfactory, although its properties are not ideal. It provides weight for thermal neutrons and gamma radiation, and the hydrogen nuclei present in the water of hydration accomplishes fast neutron scatter.

For an effective shield it is important to provide concrete of a uniform density and to ensure that it is placed in a manner calculated to minimise the effects of shrinkage. For this reason quality controlled concrete is always specified for shielding and a minimum dry density laid down at the same time. The term dry density is intended to represent the condition of the concrete under operational conditions, and not its oven dry state. A convenient, if arbitrary, way of catering for this dry density condition is to specify a minimum density for 6 in. cubes wiped dry after the normal seven day curing period in water. The allowance to cover loss in weight, as between this density at seven days and that which is likely to apply under operating conditions, will vary according to the operating conditions and the nature of the aggregates used in any specific case. This difference may well vary by anything from 3 lb/cu. ft. to 10 lb/cu. ft.

In the placing of concrete of good workability in walls of massive dimensions, say up to 9 ft. thick, heat of hydration is an important factor in the achievement of a good standard for the finished product. This aspect has been emphasised from the outset by the requirement by the nuclear physicist to avoid any form of cracking especially on the faces exposed to ventilation ducts where loose dust particles created by the cracks might be caught up and conveyed in the air streams. Limits have accordingly been placed upon the height of concrete lifts for biological shielding in order to assist the release of this heat and to minimise the stresses likely to arise therefrom. There is an argument here for the use of steel shuttering rather than timber or pre-cast slabs.

Accumulation of knowledge on the physics of biological shielding and the familiarity which has grown up between the nuclear physicist and the structural engineer has led more recently to a change in the attitude of the former to the existence of cracks. They are now regarded as undesirable but not as a serious objection, except in the circumstances referred to above, and provided they do not develop as straight " through " cracks. The definition of an acceptable crack is however another matter, and the author believes that the crack would be acceptable to the physicist if the structural engineer is prepared to accept it.

Economics of Concrete Shielding

It is pertinent at this stage to consider the economics of concrete shielding. Since the specified thickness of a shield is inversely proportional to its density there may be advantages in using heavier aggregates.

Table No. 1 may be regarded as a broad guide to the cost of concretes of varying densities as placed in the Windscale, Calder and Dounreay areas based upon market prices for the aggregates in 1957, and at Winfrith Heath based on prices in 1959.

Table 1

Concretes used for Biological Shielding

Site	*Aggregate*	*Cost of Aggregate per ton*	*Mix*	*Density at 7 days*	*Mean 28 day Strength*	*Cost per cu. yd.**	*Cost per ton*
Calder "A" and "B"	Whinstone	37/–	0·52 water 1 cement 2·25 sand 1·30 ¾" Agg. 3·88 1½" Agg.	159·4	5927	125/–	65/–
Calder "B"	Esket Limestone	19/6	·55 water 1 cement 2.25 sand 4·75 ¾" Agg.	152	4587	103/-	56/6
Dounreay	Natural Gravel	16/–	0·46 water 1 cement 2·12 sand 1·65 ¾" Agg. 2.48 1½" Agg.	151·4	6303	105/–	57/6
Dounreay	Barytes	£17	0·55 water 1 cement 3·62 sand 7·26 ¾" Agg.	220·2	4225	1400/–	527/–
Dounreay	Iron Shot	£28	0·30 water 1 cement 0·41 ·05" Agg. 7·59 ·125" Agg.	340·3	6850 7 day Strength	2500/–	605/–
Winfrith A.E.E.	Warmwell Gravel	15/3	·59 water 1 cement 1·96 sand 3·08 Agg.	145	4322	92/6	53/–

* Exclusive of reinforcement and shuttering

It will be seen that normal locally occurring aggregates appear to be the most economic means for providing a biological shield, provided that a steel thermal shield is used well. Further research might show that with the omission of a steel thermal shield a concrete biological shield, made from normal aggregates, could show economies over the Calder Hall design.

Space considerations however do sometimes dictate the use of heavy aggregates, particularly for pre-cast shielding blocks in special infilling areas around unavoidable openings or clusters of pipe penetrations etc., and advantages in space and convenience of handling compensate to some extent for their initial high costs.

The figure for barytes concrete used in the table are based on materials from U.K. sources. It is now possible to purchase barytes from the Continent at rates considerably below this figure.

Experiments are going on at the present time with Canadian Ilmenite as a heavy aggregate which would probably give a density of approximately 240 lb/cu. ft. Apart from showing economic advantages over Barytes, Canadian Ilmenite has better handling qualities.

The Biological Shield and the Need for Research

When approaching the design of a concrete biological shield the designer is faced with several conditions some of which can be stated reasonably well and others which are somewhat vague.

Ideally the shield is a box, and from a design point of view this assumption could be regarded as valid, but the vast numbers of penetrations for cooling gas ducts, air ducts, sampling tubes, charge and discharge tubes, shut-off rods, etc. must be catered for in detail, as many of these openings create hot spots in the shield thus inducing large local thermal stresses. In addition, secondary shielding must sometimes be provided to stop radiation from secondary sources.

Temperature conditions arising from neutron heating, which are normally specified by the physicist, and from heat transference which can be assessed through the thickness of floor, walls, and roof are basic design issues, to be combined with the normal structural loads which are imposed upon the shield.

Quite clearly its shape has a direct bearing upon the stresses set up within it due to temperature movements, and ideally a shield circular in plan meets this requirement best from a stress point of view. However, detailed aspects of associated plant rooms situated around the outside and also requiring shielding, may well invalidate such idealistic form, unless it is possible to introduce expansion joints in strategic places.

Movement of the shield relative to the core and to the pressure vessel is of paramount importance and must be kept to an absolute minimum, and for this reason fixity between roof, walls, and foundations is therefore generally sought. It might be argued that some form of sandwich or laminated construction would be the best answer to the temperature problem but the avoidance of relative movement between different leaves of the shield on the one hand and with the core on the other, militate against this conception.

The design of the shield has so far generally followed conventional practice. Concrete has been assumed to take no tension, and a low modulus of elasticity of 2,000,000 has been assumed to allow for creep. But of course the designer must acknowledge that little is known of :—

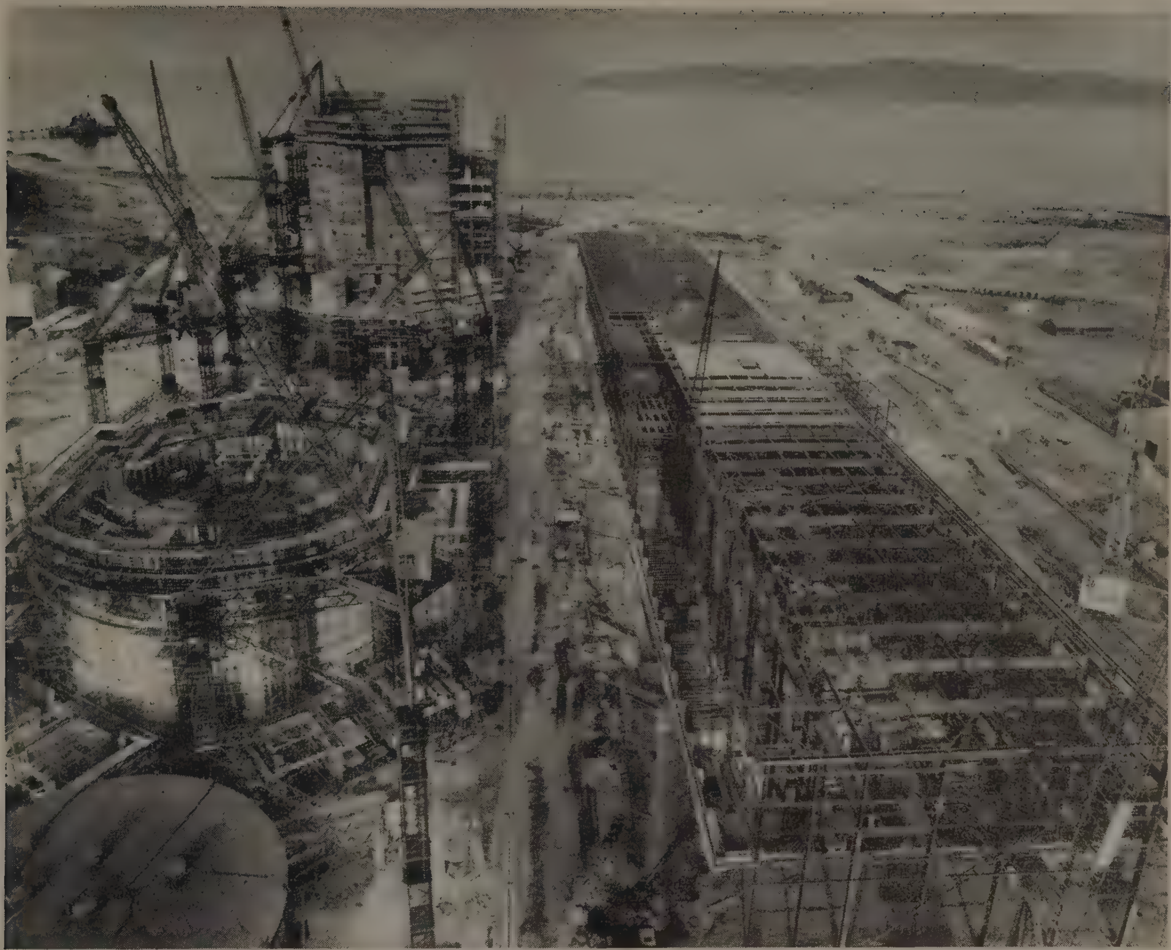

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Fig. 11.—Hunterston Nuclear Power Station under construction

a) The full extent of the effect of creep.
b) The effect of temperature on the modulus of elasticity.
c) The effect of differential temperatures.

At Calder the temperature gradient through the roof was three times as great as that through the walls. Under temperature conditions, the roof would then tend to push the top of the walls in an outward direction and an allowance for this was made in design. On the other hand, the roof was constructed some 15 months after the walls had been cast. Long term differential shrinkage is therefore bound to take place between the top of the walls and the roof itself thus providing some form of relief from these temperature stresses.

The vagueness which exists around the assumptions made above, leads one to consider some of the other properties of concrete, and whether the generally accepted behaviour of this all important product of the laboratory assistant or the labourer at the concrete mixer is as valid as it might be. Indeed evidence on the behaviour of massive reinforced concrete structures at elevated temperatures is almost non-existent and it may well be that the assumptions for design made so far are somewhat unrealistic.

With a view to establishing some measure of working knowledge upon this subject a programme of long term research has been undertaken by the D.S.I.R. on two similar reactor shields. One at Calder and one at Chapelcross. In these shields similar in all respects, except for the use of different aggregates, strain gauges, moisture content gauges, thermocouples and joint movement indicators have been installed, and it is hoped that these will provide for the benefit of future designers more reliable information on the following:—

1. Stresses set up by heat of hydration.
2. Shrinkage.
3. Creep.
4. Modulus of elasticity.
5. Moisture content and moisture movement.
6. Thermal conductivity and the effect of moisture content upon it.
7. The effect of a high internal temperature rise, if possible superimposed upon,
8. A high temperature gradient.

It would also be desirable to know more about the heat of hydration of different cements.

Other programmes of research have more recently been launched on some of the C.E.A. Nuclear Power Stations including Berkeley and Hunterston and it is hoped that the collective information so gained will lead to greater confidence in design and a more economic approach.

Steel Containment Buildings

These have already been discussed in detail elsewhere but a few aspects of large steel containment buildings are worth repetition :—

1. They are the ultimate physical protection to the public against the release of harmful fission products arising from an incident.
2. They are essentially site built from factory made components.
3. Incident, rather than operating conditions, govern design.

4. Large leak-proof penetrations are required.
5. Steels having the best fusion welding quality and a reserve notch ductility against danger of brittle fracture are needed. Quite apart from the chemical composition, and tensile and bend tests of these steels for site welded construction, the Charpy impact value must be met under test. Suitable steels are known as N.D.1, N.D.2, N.D.3 and N.D.4, and have Charpy impact values ranging from 20 ft. lb. at 0°C. to 20 ft. lb. at —45° C. A further grade of steel known as P.5 comes within this range with a Charpy value of 35 ft. lb. at 0°C. and is approximately equivalent to N.D.2.

Certain U.K. reactors have already been, or are being, built at Harwell, Dounreay and Windscale, and the wafer thickness of the A.G.R. containment building membrane raises a good many problems, as construction techniques of a containment building such as A.G.R. subject to buckling stresses are almost non-existent. It is of course clear that construction and design are closely linked, for the inability of the contractor to build within the tolerances laid down by the structural engineer in the design of his membrane will invalidate his design. Nevertheless, the structural engineer must predetermine the permissible shape imperfections to obtain a design basis for the structure. These shape imperfections will arise from a combination of many operations such as shaping in the shops, handling, transport, partial fabrication on manipulators at the site, stacking, lifting into position, allowance for sag, allowance for shrinkage in welded seams, and an understanding of appropriate techniques for minimising peaking and flattening in welded seams.

Research and Development

Codes.—The design and construction of these buildings have brought with them certain problems which have revealed a weakness in our present knowledge, particularly that concerning the design of large site fabricated spherical shapes subject to vacuum conditions. These buildings are hybrids and are not covered by any single Code or Specification. At the present time design aspects for spherical shapes have been based on Section VIII of the A.S.M.E. Code for Unfired Pressure Vessels, and the fabrication and inspection to the appropriate sections of B.S. 1500.

Accuracy.—Permissible tolerances for vessels of this size are not catered for at all, except by the possible extrapolation of curves for small vessels and this provides tolerances totally unacceptable for buildings of this nature, so that the judgment of the engineer alone, and his personal assessment of the contractor's ability to build accurately, quickly, is the sole means for laying down the limits of constructional imperfections.

A programme of research is being worked out in an effort to define if possible, the laws which govern the relation between imperfections in spherical shapes and the effect these have upon the ability of the membrane to resist buckling arising from vacuum conditions.

Testing of Non Stress-Relieved Vessels. —At the present time three Codes are in existence, specifying different levels for air pressure tests for non stress-relieved vessels. The A.S.M.E. stipulates 25 per cent, the A.P.I. A.S.M.E. stipulates 10 per cent and B.S. 1500 stipulates 15 per cent above the design working pressure. Tests for large vessels by means of a compressible gas undoubtedly carry with them very real hazards, and for this reason alone, limitations of such tests must be kept in mind.

The design pressure governing the membrane thickness of containment buildings is not necessarily the working pressure—indeed it may be far in excess of it. Nevertheless, the penalty for failure to perform its task is very grave, and there should be an authoritative Code which lays down test procedure limitations.

Welding.—There were nearly $2\frac{1}{2}$ miles of full strength in situ hand made fusion welds in plate varying from 1 in. to $1\frac{3}{4}$ in. in thickness on the Dounreay Sphere. There will be nearly 2 miles of similar welds in plates varying from $\frac{1}{2}$ in to $1\frac{3}{4}$ in. in thickness on the A.G.R. Peardrop. The need for continuing urgent research into the use of in situ machine welding to replace part or all of this hand welding is all too evident, and no efforts should be spared in this direction.

Concrete Containment Buildings

Concrete containers have hitherto been regarded as unsuitable because of the design conditions—high temperature, high internal pressures or high external pressures, combined with leak rates as low as 0.1 per cent of the Container's volume in 24 hours. Concrete, it was felt was suitable only for very low powered reactors.

An opportunity has now presented itself in the construction of a high temperature facility known as HERO (Hot Experimental Reactor Zero Energy), as a " side issue " to A.G.R. at Windscale. Temperature conditions from radiation do not arise but a temperature gradient of 60°C. has to be catered for, whilst internal and external pressures are unlikely to exceed 10 in. water gauge.

The reactor room with its associated plant rooms is therefore being designed as a concrete containment building to withstand these conditions with the proviso that leakage at the above pressures does not exceed 5 per cent of the volume within 24 hours.

Special attention will need to be paid to construction joints, joints between floors and walls and roofs, and the sealing details around doors and other wall penetrations.

Research and Experiment—Concrete

Small scale experiments already carried out on the leakage of air through concrete confirm the belief that a properly designed and compacted concrete should meet the conditions laid down for HERO and experience on this may give rise to further confidence in the use of concrete as a material for containment purposes.

It is however a subject for suitable long term basic research for the Author is of the opinion that the laws which govern the fluid-retaining qualities of concrete are different from those which govern the flow of air or gas through its thickness.

Health and Safety

It is recognised that when factories and process plants are built, the requirements of the Factory Acts must be observed. When toxic and radiation hazards exist, special precautions must be taken such as the use of impervious surface finishes to facilitate decontamination, and stringent limitations upon the use of combustible materials.

In the atomic energy field, where district hazards could arise from an unforeseen incident, and containment buildings are designed against such an eventuality, the designer must give due consideration to his designs and to provide whatever safeguards are necessary or

Fig. 12.—Dounreay—The Fast Reactor

desirable against failure. He owes this to the public at large.

The temptation to err too far on the side of safety with its attendant economic effects must however be geared to the necessity for designing with reasonable economy. The dividing line between "Safety at any cost" and "Safety with reason" may not always be clearly defined, but the structural engineer must strive in his designs to satisfy his professional judgment, both as an engineer and also as guardian of the public safety.

Philosophy of Structural Design

The master construction programmes covering the chain of developments since 1946 have set target dates for design and construction which were deliberately difficult to achieve, for the nation's economy demanded early and successful results.

Throughout these years of concentrated research and development in the nuclear field, scientist and engineer have worked almost hand in hand pioneering work which from the scientific point of view was often fast approaching obsolescence before it was finally

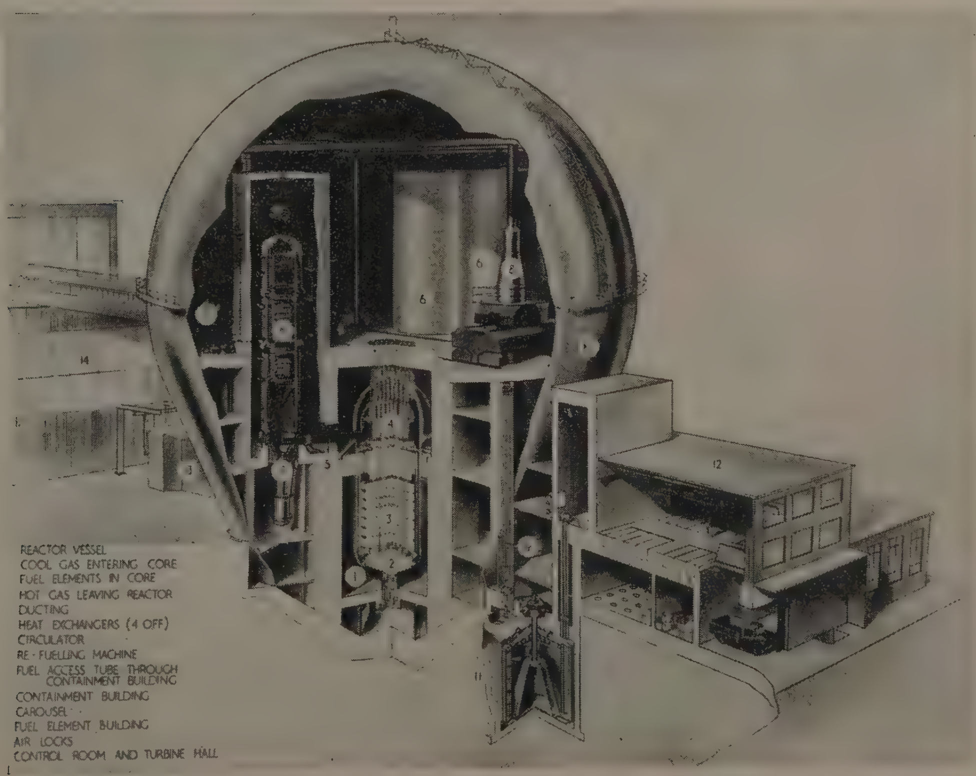

Fig. 13.—Windscale—The Advanced Gas Cooled Reactor (A.G.R.)

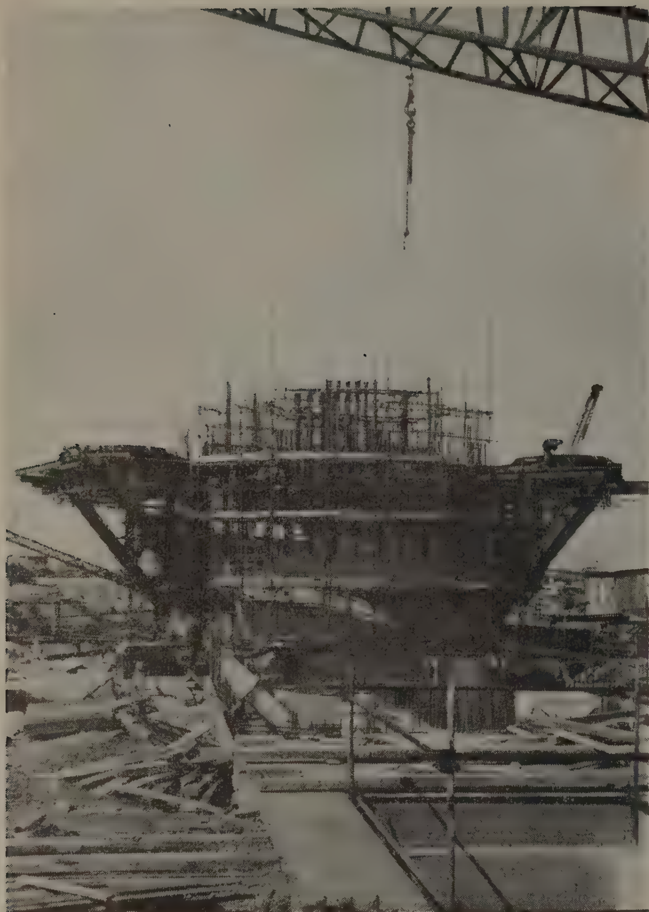

Fig. 14.—Windscale—The A.G.R. under construction

constructed. And when one considers in retrospect the achievements of the past 14 years the results are easy to demonstrate but the efforts required to achieve them are so easily overlooked, for the battle to translate the requirements of the nuclear physicist into engineering realities and the battle to keep pace with the master construction programmes have demanded much of the structural engineer.

His responsibility in this latter respect has been particularly severe for the obvious reasons that his designs and detail drawings from foundations upwards were always governing the commencement of the main construction work on site, and any delays at this initial stage were likely to affect adversely all following trades.

On building construction generally he has been constantly faced with alterations, omissions, additions, and shortage of essential design information, all of which has had to be dealt with in a manner as to ensure that his essential target dates in the programmes were met. How then with all these unexpected demands made upon him can the structural engineer satisfy his engineering conscience and at the same time serve his scientific colleagues in such a manner that he does not become the weak link in the chain of development? It is, of course, in his approach to design, and his own reasoned judgment of the likelihood of future demands for additional facilities being made by the research teams. He must provide every reasonable means for future extensions to buildings where their siting makes any extensions a possibility. He must endeavour to keep his mind fluid and his designs for superstructures simple, for in so doing, he has greater freedom to deal with progressive changes which inevitably arise in work of a pioneering nature.

On the other hand his attitude towards the design and the construction of biological shields and of containment buildings must be tempered by prudence. The penalty for these structures failing in their allotted tasks is very obvious. The public quite rightly is sensitive to the possible, if unlikely, release of harmful invisible products of fission. It is natural, therefore, that most designers of biological shields have used the "conventional" approach to design and the long established techniques of construction, whilst designers of containment buildings have been cautious in the selection of materials and in the demonstration of the quality of their construction. Nevertheless courage in his own judgment has also been necessary, when presented with problems not covered by existing codes of practice.

Conclusion

Atomic Energy has offered Britain a timely addition to its industrial resources and therefore to its material welfare, and future generations will judge this generation by the manner in which present opportunities are used for the good of all people.

The contribution made so far by the Structural Engineer in the field of Atomic Energy as presented by hard facts has been of paramount importance. In this new industry his duty is to design simply and for flexibility, to build quickly and to build well. He must acknowledge that the efficiency of the Calder Hall reactors, largely a function of their operating temperatures and pressures, was limited by site welding techniques and the quality of available steels. Nevertheless, the lessons learned from these reactors, together with advances since made in design and construction techniques will enable more recently built gas cooled power reactors to operate at higher temperatures and pressures, and therefore at a higher efficiency rating.

The Structural Engineer must be ready to meet the challenge of the Nuclear Physicist. It is essential therefore that research and development should continue to be pressed forward in a spirit of urgency, to ensure that lack of knowledge in these highly important fields does not constitute a bottleneck in the advances which must inevitably develop in the design and construction of nuclear power reactors. Therein lies the greatest contribution of the Structural Engineer in the field of Atomic Energy.

The Author wishes to express his thanks to the Managing Director of the United Kingdom Atomic Energy Authority (Industrial Group) for permission to publish his paper.

Acknowledgments are due to the Atomic Energy Authority, the C.E.G.B., and S.S.E.B., for permission to publish the construction photographs.

Institution Notices and Proceedings

PRESENTATION TO H.R.H. PRINCE PHILIP, DUKE OF EDINBURGH, OF HIS CERTIFICATE OF HONORARY MEMBERSHIP

The President, Mr. Lewis E. Kent, accompanied by Mr. Gordon S. McDonald (immediate Past President) and the Secretary were greatly honoured by being given an audience by the Duke of Edinburgh on the 13th November, when they were privileged to present to His Royal Highness, on behalf of the Council, his certificate of Honorary Membership of the Institution of Structural Engineers. The audience lasted some fifty minutes, during the course of which the Duke showed his keen interest in the work of the Institution.

ORDINARY GENERAL MEETING

An Ordinary General Meeting of the Institution of Structural Engineers was held at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 26th November, 1959, at 5.55 p.m. Mr. Lewis E. Kent, B.Sc., M.I.Struct.E., M.I.C.E., (President) in the Chair.

The following members were elected in accordance with the Bye-Laws. Will members kindly note that the elections, as tabulated below, should be referred to when consulting the Year Book for evidence of membership.

Students

Ardern, Bruce Edward, of Auckland, New Zealand.
Athmani, Roderick Karl, of Nairobi, Kenya.
Barnard, Brian William, of Hemel Hempstead, Hertfordshire.
Basu, Mrinalkanti, B.Sc., of London.
Cheong Kow Kee, of Ipoh, Perak, Malaya.
Donoghue, Karl Thomas, of Nairobi, Kenya.
Erasmus, Jan Hendrik, of Bolton, Lancashire.
Fearnley, John, of Leigh, Lancashire.
Feltoe, Brian, of Bulawayo, Southern Rhodesia.
Gaynor, David Donald Emerson, of Bristol.
George, Reginald Anthony, of Caerphilly, Glamorganshire.
Gilmour, Peter James, of Manchester.
Goodall, Keith James, of Durban, South Africa.
Hepper, Edward James Mortimer, of Tunbridge Wells, Kent.
Hoole, Peter, of Bolton, Lancashire.
Humphrey, Arthur Thomas, of Chelmsford, Essex.
Johnson, James Charles, of Wellington, New Zealand.
Johnston, Selwyn George, of Auckland, New Zealand.
Jones, William Leslie, of Cwmbran, Monmouthshire.
Kar, Ganga Gobinda, of London.
Kwong Tak Cheong, of Kowloon, Hong Kong.
Marais, Dennis, of Johannesburg, South Africa
Marsh, Warren Arthur, of Bolton, Lancashire.
Naphade, Shashikant Trimbak, of Indore (M.P.), India.
O'Hanlon, Terence Patrick, of Birkenhead, Cheshire.
Partington, James Roy, of Farnworth, Lancashire.
Pettersson, Erika Maria Franziska (Miss), of Kitwe, Northern Rhodesia.
Salako, James Adebayo, of London.
Shenolikar, Gurunath Madhav, of Bombay, India.
Simmons, Peter Francis, of Welling, Kent.
Skilton, David Alan, of Auckland, New Zealand.
Tang Kok Yue, of Hong Kong.
Tillman, Roy Anthony Frederick, of Johannesburg, South Africa.
Watson, Robert William, of Darlington, Co. Durham.
Wong Yee Khow, of Manchester.

Graduates

Abbasi, Abdus Salam, B.Sc., of Karachi, Pakistan.
Adams, Robert Henry, of Greymouth, S. Island, New Zealand.
Ali, Mohamad Nasir, B.Eng., of Bangalore, Mysore State, India.
Anderson, George Eric, of Middlesbrough, Yorkshire.
Barnard, John Desmond Nico, B.Sc., of London.
Barraclough, Gordon, of Sheffield.
Basu, Nirmal Kumar, B.E., of Calcutta, India.
Bathe, Daniel David, of Belfast, Northern Ireland.
Batkin, Edward Roger, of London.
Benster, Norman Alan, B.Sc., of London.
Bishop, Bryan Arthur, of London.
Boere, Anton Hendrik, of Johannesburg, South Africa.
Burgess, Kenneth Arthur, of Manchester.
Cannon, John Charles, M.A., of Knutsford, Cheshire.
Chakravorty, Deb Kumar, B.E., of Calcutta, India.
Chapple, John David Lincoln, of Auckland, New Zealand.
Chen, Park Kuen, M.Sc., of Harrisburg, Pa., U.S.A.
Clayden, Kenneth John Charles, B.Sc., A.M.I.C.E., of Broxbourne, Hertfordshire.
Cowley, Brian Ernest, of London.
Day, Geoffrey Ralph, of Bristol.
De Sousa, Arduino Orlando, B.Eng., of London.
Duly, Victor Ernest John, of Ilford, Essex.
Fleming, Ian Doyle, B.Sc., of Durban, Natal, South Africa.
Ghosh, Sisir Kumar, B.E., of Calcutta, India.
Ghosh, Srikumar, B.E., of London.
Gill, Michael Brendan Mary, B.E., of London.
Gregory, John James Conrad, of Redditch, Worcestershire.
Grimshaw, Rodney Erskine, of Manchester.
Harpalani, Dayal Sunderdas, B.E., of Bombay, India.
Hastings, Philip Guy, of Bristol.
Heard, Michael John, of Woodford Bridge, Essex.
Hiles, Kenneth Rex, of Nottingham.
Hurden, Michael Eric, of London.
Johnson, Gerald Michael, of Burton-on-Trent.
Joshi, Ratnakar Rajaram, B.E., of Bombay, India.
Kambli, Digambar Ramchandra, of Bombay, India.
Kelly, James Francis, B.Eng., of London.
Kulkarni, Prabhakar Durgaram, of Jodhpur, Rajstan State, India.
Kundu, Haradhan, B.Sc., of Sunderland, Co. Durham.
Lazenby, David William, of Weybridge, Surrey.
Leung Hoi Wah, of Hong Kong.
Lim Wee Kiat, of London.
Lipp, Lawrence, of Stanmore, Middlesex.
Loh Chow Shin, of London.
Mackintosh, John Grant, of Montreal, P.Q., Canada.
Mahmood, Abdul Rafi, B.Sc., of Warsak, Peshawar, West Pakistan.
Matharu, Tara Singh, of London.
Mazumdar, Satyendu Kumar, B.E., of Calcutta, India.
Minett, Peter Burne, of Feltham, Middlesex.
Mok Yee Chor, B.Sc., of Middlesbrough, Yorkshire.
Moodie, Gordon, of Thornaby-on-Tees, Yorkshire.
Nagaraj, Janniah, B.E., of New Delhi, India.
Nagarkatti, Ramdas Rangarao, B.Eng., of Bombay, India.
Nakendra, S., of Kuala Lumpur, Malaya.
Natarajan, Lalgudi Ramachandra, B.E., of Madras, India.
Nayak, Pundalik Vaman, B.Eng., of Bombay, India.
O'Byrne, Kevin Francis, B.E., of Nairobi, Kenya.

OJUKWU, Emmanuel Ndubueze, of Lagos, Nigeria.
OSBORNE, Ivan William, B.Sc., of London.
PARKINSON, Joseph Maurice, B.Sc., of Gateshead, Co. Durham.
PATTISON, William Lunn, A.M.I.Mun.E., of Romford, Essex.
PERRY, David Roland Silas, B.Sc., of London.
PRASAN, Srinivas, B.Sc., B.E., of Durgapur P.O., West Bengal, India.
PRETSELL, James, B.Sc., of Henlow, Bedfordshire.
PUNCH, Michael John, B.E., of London.
RAO, Korcherlakota Ramchandar, B.Sc., of Lucknow, U.P., India.
ROSS, Peter Skene, B.Sc., of Ilford, Essex.
SAGE, Griffith, of Aberdare, Glamorganshire.
SCHLAEPFER, John William, of London.
SCOTT-WHITE, Raymond, B.Sc., of Croydon, Surrey.
SINHA ROY, Pijush Kumar, B.E., of Calcutta, India.
SMITH, Frank, of Stockton-on-Tees, Co. Durham.
SNELL, John Alfred, of Dagenham, Essex.
SOUTHWELL, John, of London.
SPEED, Donald James, of London.
SPILLER, Joseph Anthony, of Manchester.
STONE, Peter Albert, of London.
SULAIMAN, Izzat Bakir Ahmed, B.Sc., of Cardiff.
SULLIVAN, Anthony, of Middlesbrough, Yorkshire.
SUTTON, Allan Fauconnier, of London.
SZE, Peter, of London.
TANG KWOK KEE, B.Sc., of Hong Kong.
THILWIND, John Howard, of Rainhill, nr. Liverpool.
TILBURY, Frank Charles, of London.
UTTAMCHANDANI, B.R., B.E., of Indore (M.P.), India.
VISWANATH, Sindhaghatta, of Bombay, India.
WARD, Charles Henry, of London.
WILLIS, Edwin Joseph, B.Sc., of Southampton.
WILSON, Geoffrey, B.Sc., A.M.I.C.E., of Mitcham, Surrey.
YAWITCH, Michael Faivel, B.Sc., of Johannesburg, South Africa.
YONG CHO YEE, of Pasadena, California, U.S.A.
YUEN KAI MENG, B.C.E., of Melbourne, Victoria, Australia.

ASSOCIATE-MEMBERS

HOME, Kenneth, B.Sc., of Leicester.
PAUL, Debi Prosad, B.E., of London.
SHARPE, Norman Renshaw, of London.

MEMBERS

COOK, Ernest James, B.Sc., A.M.I.C.E., of Merstham, Surrey.
KARKARIA, Jamshedji Cawasji, B.E., M.I.C.E., of Nagpur, India.
ZWEIGENTHAL, Stefan Josef Heinrich, of Johannesburg, South Africa.

TRANSFERS

Students to Graduates

DOWELL, Peter James, of Wirral, Cheshire.
GAGE, Roger Anthony, of North Harrow, Middlesex.
GRANAGAN, William, of Liverpool.
HALL, Peter William, of Allenton, Derby.
HARPER, John Frederick, of Durban, Natal, South Africa.
HURST, Bertram Lawrence, B.Sc., of London.
MITCHELL, George Brian, of Liverpool.
REITH, Robert Davidson, of London.
SMITH, David Harry, of Brentwood, Essex.

Graduates to Associate-Members

ALLAWAY, Godfrey Walter, of Stockton-on-Tees, Co. Durham.
BHOGAL, Ajit Singh, of Mombasa, Kenya.
BROWN, Gordon Sidney, of Old Coulsdon, Surrey.
CLARKE, John Richard, of London.
DASGUPTA, Amitava, B.E., of Durgapur, Dt. Burdwan, India.
DIXIT, Vasant Damodar, B.E., of Bombay, India.
GADSBY, John William, of Wentbridge, Yorks.
GASIOROWSKI, Waclaw, of London.
GATES, Ian Norman, of Wallasey, Cheshire.
GEESON, David Arthur, of London.
GRIFFITHS, Geoffrey Arthur, of Northfleet, Kent.
GRZEDA, Aleksander Stanislaw, of London.
GUHA BISWAS, Satyendra Mohan, B.E., of London.
GUPTA, Chandan Kumar, B.E., of Feltham, Middx.
HEGARTY, Michael, of Charleston, West Virginia, U.S.A.
HIGHAM, Roland, of Bolton, Lancashire.
LAKE, John Brian Francis, of Amersham, Buckinghamshire.
LEUNG TING KUI, B.Sc., of London.
LINDOP, John Furber, of Crewe, Cheshire.
McCARTNEY, Alan Hugh, B.Eng., of York.
MIDDLETON, James Henry, of Corby, Northamptonshire.
MOORE, Philip Walter, of Cranford, nr. Hounslow, Middlesex.
NJOKU, Richard Alozieuwa, of Aba, Nigeria.
OMISORE, Ezekiel Iyiola, of Ibadan, Nigeria.
SARKAR, Tarit Kumar, B.E., of London.
SAVE, Arun Baburao, B.E., of London.
SCHOFIELD, Alfred, of Aston, nr. Sheffield.
STREET, William Raymond, of Sale, Cheshire.
SYDENHAM, Richard Sidney, of Ilford, Essex.
THOMPSON, Geoffrey, of Leeds.
VIRGIN, Kenneth James, A.R.I.C.S., of Morden, Surrey.
WHITAKER, Norman, of Bury, Lancashire.
WORK, James, of Glasgow.
YATES, Peter Ronald, of Wallasey, Cheshire.

Associate-Members to Members

BENTLEY, John Johnson, of London.
BHATTACHARYA, Sunil Kumar, B.Sc., A.M.I.C.E., of Calcutta, India.
DUNCAN, George Emerson, of London.
GODFREY, David Alec, B.Sc., of Northwich, Cheshire.
GOLDSTEIN, Adolf, B.Sc., A.M.I.C.E., of London.
HENEY, Edward, A.M.I.C.E., of Johannesburg, South Africa.
LAING, Gordon Smith, B.Sc., A.M.I.C.E., of Johannesburg, South Africa.
MACDONALD, Henry Gillies, A.M.I.C.E., of Bearsden, Dunbartonshire.
MUIR, Peter, of Salisbury, Southern Rhodesia.
THOMAS, Norman, A.M.I.C.E., of Bramhall, Cheshire.
WHITLAM, Edwin Frederick, M.Sc., A.M.I.C.E., of Orpington, Kent.
WILSON, Francis Stanley, of Guisborough, Yorkshire.

OBITUARY

The Council regret to announce the deaths of Lt.-General Sir Dudley Stuart COLLINS, K.B.E., C.B., D.S.O. (Honorary Member); Jack DUNN, Howard HARDING, Joseph KERSHAW (Senior), Robert James WILKINS (Members); Herbert William MANAUER, Tom Bradley SHORE (Retired Members); Captain H. J. COX, Herbert Henry HARRADENCE, Trevor John LIVESEY, John RENN, William Stanley SHARP, John Griffith THOMAS (Associate-Members); Sudhakar Waman BELSARE (Graduate).

FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

Thursday, 14*th January*, 1960.

Ordinary Meeting at 6 p.m., when a paper will be given by Mr. D. Lax, M.I.Struct.E., and Mr. F. T. Bunclark, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., entitled "The Design and Construction of the new Assembly Building for the Ford Motor Company Limited, Dagenham."

The following additional meeting has been arranged since the Sessional Programme went to press. Due to the large number of applications for visitors' tickets the proceedings will be relayed to the meeting hall at No. 10, *Upper Belgrave Street, by kind permission of The Royal Institution of Naval Architects.*

Thursday, 21*st January*, 1960.

Ordinary Meeting at 6 p.m., when a paper will be given by Mr. A. R. Mackay, A.M.I.Struct.E., on "Lightweight Fire Protection and the Structural Engineer."

Thursday, 28*th January*, 1960

Ordinary General Meeting for the election of members 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper will be given by Mr. T. C. Waters, M.I.Struct.E., on "The Structural Engineer in the Field of Atomic Energy."

Thursday, 11*th February*, 1960

Ordinary Meeting at 6 p.m., when a paper on "Brinsworth Steel Strip Mill" will be given in two parts, Part I by Mr. Donovan H. Lee, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mech.E., (Member of Council), and Mr. G. O. Kee, B.Sc., A.M.I.C.E., and Part II by Mr. N. Lancaster.

Thursday, 25*th February*, 1960

Ordinary General Meeting for the election of members 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper will be given by Mr. A. R. Dykes, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "Folded Plate Construction : An Investigation of Collapse Conditions."

Thursday, 10*th March*, 1960

Ordinary Meeting at 6 p.m., when three papers on "New Developments in Structural Analysis and Design by means of the Electronic Computer" will be given as follows :—

Mr. L. Morgan : "Application of an Electronic Digital Computer to Structural Steel Design."

Dr. E. Lightfoot, M.I.Struct.E., A.M.I.C.E., and Mr. F. Sawko : "The Analysis of Grid Frameworks and Floor Systems by the Electronic Computer."

Dr. D. M. Brotton, A.M.I.Struct.E., : "Elastic Critical Loads of Multi-Bay Pitched Roof Portal Frames with Rigid External Stanchions."

Thursday, 24*th March*, 1960

Ordinary General Meeting for the election of members 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper on "Research for the Concrete Industry" will be given by Dr. A. R. Collins, M.B.E., M.I.Struct.E., M.I.C.E. (Member of Council).

Members wishing to bring guests to the Ordinary Meetings announced above are requested to apply to the Secretary for tickets of admission.

ANNUAL DINNER, 1960

The Annual Dinner will be held at the Dorchester Hotel, London, W., on Friday, 25th March, 1960.

HONOURS AND AWARDS

In offering their sincere congratulations to the following members on the distinctions recently conferred upon them, the Council feel they are also expressing the good wishes of the Institution.

Order of the British Empire—O.B.E.
Mr. R. W. Bishop (Associate-Member)

Hon. M.Sc. University of Leeds—
Mr. P. H. T. Gooding (Member)

NIGERIAN SECTION

The Council have sanctioned the formation of a Nigerian Section of the Institution with headquarters in Lagos. The Honorary Officers and Committee members are as follows :—

Chairman : Mr. J. W. Henderson (Member).
Honorary Secretary : Mr. A. Brimer (Associate-Member).
Assistant Honorary Secretary : Mr. C. O. Idowu (Associate-Member).
Committee Members : Messrs. H. A. Brown, B. M. Hudson, J. E. Kay, J. A. Olaniyan.

Communications should be addressed to Mr. A. Brimer, A.M.I.Struct.E., Brimer, Andrews & Nachshen, Private Bag Mail 2295, Lagos, Nigeria.

REPRESENTATION

The following Institution representatives have been appointed :

DSIR—Standing Consultative Conference on Building Research and Development—

Professor S. R. Sparkes

BSI Chemical Engineering Industry Standards Committee—

Mr. J. S. Terrington

Exploratory Committee to be convened by the Institute of Physics for the purpose of considering how best to ensure adequate British participation in international conferences in the field of stress analysis—

Dr. E. Lightfoot
Professor P. B. Morice

ALUMINIUM DEVELOPMENT ASSOCIATION RESEARCH SCHOLARSHIP

A research scholarship in the use of light alloys in structural engineering is offered every third year by the Institution of Structural Engineers in collaboration with the Aluminium Development Association. The duration of the scholarship is two years and the value £600 per annum.

The next award will be made this year to date from October 1st, 1960.

Details and application forms are obtainable from the Secretary of the Institution of Structural Engineers. Completed application forms should be sent in to reach the Secretary by March 31st, 1960.

THE MAITLAND LECTURE COMPETITION

A competition will be held for the Maitland Lecture which will be given during the Session 1960-61. Members and Associate-Members of the Institution are invited to submit a written lecture, the subject of which may be on research, design or construction in the field of structural engineering, with special reference to new developments.

The winner of the Competition will be awarded the Maitland Silver Medal and Premium (value £100).

Lectures submitted for the Competition must be received by the Institution not later than the 31st March, 1960. Further information regarding the conditions of the Award may be obtained on application to the Secretary.

INDIA

The following publications may be obtained from Mr. J. G. Bodhe, B.E., M.I.Struct.E., of K. R. Irani & Co., 24-26, Dalal Street, Fort, Bombay, one of the Institution's representatives in Bombay :

Charter and Bye-Laws . . . Rs.1.75 n.p. (postage included).

Examination Papers, per set . . . Rs. 2.00 n.p. (postage included). Remittances must accompany requests.

Branch Notices

LANCASHIRE AND CHESHIRE BRANCH

The following meetings have been arranged :

Tuesday, 19th January, 1960

Joint Meeting with The Institution of Civil Engineers.

Mr. D. R. R. Dick, B.Sc., M.I.Struct.E., M.I.C.E., on " Berkeley Power Station."

Friday, 5th February, 1960

Annual Dinner Dance.

In the Derby Suite, Midland Hotel, Manchester.

Monday, 15th February, 1960

Mr. J. D. Davies, M.Sc.(Eng.), A.M.I.Struct.E., A.M.I.C.E., on " Some Problems in Cylindrical Tank Analysis."

Wednesday, 2nd March, 1960

Joint Meeting with the Institute of Welding, 7.15 p.m.

Mr. A. V. Hooker, M.I.Struct.E., M.I.C.E., on " Welding in the Structural Industry."

Thursday, 10th March, 1960

Junior Members' Evening for the presentation of three 20-minute papers by the following Branch members :

Mr. G. Evans, A.M.I.Struct.E.: " The Design and Construction of the Plutonium Criticality Facility Building at Dounreay."

Mr. T. L. Holden (Graduate) : "The Construction of a Laminated Timber Hyperbolic Paraboloid Roof."

Mr. C. Tucker, A.M.I.Struct.E.: " British Railways —London Midland Region Electrification. Reconstruction of overbridges between Crewe and Manchester."

In the New Lecture Theatre, U.K.A.E.A. (I.G.) Headquarters, Risley, nr. Warrington.

Friday, 18th March, 1960

Dr. D. D. Matthews, M.I.Struct.E., M.I.C.E., (Vice-President) will present a paper from notes provided by M. Esquillan on " The Design and Construction of the Exhibition Palace of the National Centre of Industries and Technology, Paris." It is hoped M. Esquillan will be present.

Unless otherwise stated the above meetings will be held at the College of Science and Technology, Manchester, commencing at 6.30 p.m. Light refreshments will be available from 5.45 p.m.

MERSEYSIDE PANEL

The following meetings have been arranged :

Thursday, 14th January, 1960

Mr. J. B. Ashton, M.I.Struct.E., on " A Swiss System of Prestressed Concrete and some British Applications."

At the College of Building, Clarence Street, Liverpool.

Monday, 22nd February, 1960

Mr. E. Thorpe, A.M.I.Struct.E., on " The Design and Construction of Windscale Cartridge Cooling Ponds."

At Liverpool University, in the new Civil Engineering Building, Brownlow Hill.

Meetings will commence at 6.30 p.m. and will be preceded by light refreshments from 5.30 p.m.

Hon. Secretary : W. S. Watts, A.M.I.Struct.E., A.M.I.C.E., 11, Newchurch Lane, Culcheth, nr. Warrington, Lancs.

MIDLAND COUNTIES BRANCH

The following meetings have been arranged :

Friday, 22nd January, 1960

Mr. M. F. Palmer, M.I.Struct.E., M.I.C.E., and Mr. R. J. Fowler, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., A.M.I.Mech.E., on " Modern Methods of Fabricating Structural Steelwork."

Friday, 12th February, 1960

Joint Meeting with the Birmingham and Five Counties Architectural Association.

Mr. A. G. Sheppard-Fidler, M.A., B.Arch., L.R.I.B.A. on " Birmingham Rebuilds."

At the Birmingham Medical Institute, 36, Harborne Road, Edgbaston, Birmingham, at 6.15 p.m. Tea will be served from 5.30 p.m.

Friday, 26th February, 1960

Dr. K. C. Rockey, A.M.I.C.E., A.M.I.Mech.E., on " Web Buckling and the Design of Plate Girders."

Tuesday, 8th March, 1960

Mr. A. W. Hill, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mun.E., on " The Structural Use of Prestressed Concrete in Buildings C.P.115."

At the Electricity Showrooms, Irongate, Derby, at 6.15 p.m. Tea will be served from 5.30 p.m.

Friday, 25th March, 1960

Mr. A. W. Hill, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mun.E., on " The Structural Use of Prestressed Concrete in Buildings C.P.115."

Unless otherwise stated, meetings will be held at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 6.30 p.m. Tea will be served from 5.45 p.m.

Hon. Secretary : S. M. Cooper, A.M.I.Struct.E., " Applegarth," Hyperion Road, Stourton, nr. Stourbridge, Worcestershire.

GRADUATES' AND STUDENTS' SECTION

The following meetings have been arranged :

Friday, 15th January, 1960

Mr. R. Adams, M.I.Mech.E., A.M.I.C.E., Manager, Mechanical and Electrical Division, George Wimpey & Co. Ltd., on " Extension to the Isle of Grain, Kent Refinery, for British Petroleum Co. Ltd." The lecture will be illustrated by films and slides.

Friday, 5th February, 1960

Mr. B. W. Cooper, B.Sc., A.M.I.Struct.E., A.M.I.C.E., Birmingham Office Manager, Truscon Limited, will present a sound film and give an associated lecture on " Picture Frame Construction and Modern Wall Cladding."

Friday, 4th March, 1960

Mr. N. Rayman, Chief Structural Engineer to the City of Coventry, on "The New Coventry."

The above meetings will be held at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, commencing 6.30 p.m. Tea will be served from 6 p.m.

Hon. Secretary: H. T. Dodd, "Oakleigh," Coton Road, Whitacre, nr. Coleshill, Birmingham.

NORTHERN COUNTIES BRANCH

The following meetings have been arranged:

Tuesday, 5th January, 1960

At Middlesbrough. Mr. D. W. Cooper, B.Sc., A.M.I.Struct.E., and Dr. J. D. Geddes, A.M.I.C.E. (Graduate), on "Structures in Areas of Mining Subsidence."

Wednesday, 6th January, 1960

The above paper will be repeated at Newcastle.

Thursday, 21st January, 1960

At Newcastle. Joint Meeting with the Northern Architectural Association, commencing 7.30 p.m.

Mr. M. J. Earley, A.M.T.P.I., A.I.L.A., on "Landscape and People."

At 6, Higham Place.

Thursday, 28th January, 1960

At Middlesbrough. Joint Meeting with the Teesside Branch of the Institution of Civil Engineers, at 5.45 p.m. for 6.15 p.m.

Mr. L. R. Creasy, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., on "Economics of Framed Structures."

Tuesday, 2nd February, 1960

At Middlesbrough. Mr. N. T. Barrett, B.Sc.(Eng.), A.M.I.Struct.E., (Associate-Member of Council), on "Housing the Dounreay Fast Reactor."

Wednesday, 3rd February, 1960

The above paper will be repeated at Newcastle.

**Tuesday, 16th February*, 1960

At Middlesbrough. Mr. J. H. H. Gillespie, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "The Modernisation of British Waterways with particular reference to the South Eastern Division."

Friday, 26th February, 1960

Annual Dinner Dance.

At Tilley's Restaurant, Newcastle.

Tuesday, 1st March, 1960

At Middlesbrough. Mr. Walter C. Andrews, O.B.E., M.I.Struct.E., M.I.C.E. (Past President) on "The Provisions of the Revised British Standard for the Use of Structural Steel in Building—B.S. 449/1959."

Wednesday, 2nd March, 1960

The above paper will be repeated at Newcastle.

**Friday, 18th March*, 1960

At Newcastle. Mr. J. H. H. Gillespie, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "The Modernisation of British Waterways with particular reference to the South Eastern Division."

**Additional meetings to those announced in the printed Sessional Programme.*

Unless otherwise stated, meetings in Middlesbrough will be held in the Cleveland Scientific and Technical Institution and meetings in Newcastle will be held in the Neville Hall, commencing at 6.30 p.m., preceded by buffet tea at 6 p.m.

Hon. Secretary: P. D. Newton, B.Sc., A.M.I.Struct.E., A.M.I.C.E., c/o Richard Hill Ltd., P.O. Box 29, Middlesbrough, Yorkshire.

NORTHERN IRELAND BRANCH

The following meetings have been arranged:

Monday, 18th January, 1960

Mr. F. F. Poshitt, B.Sc., M.I.C.E., and Mr. J. A. Soya, B.Sc., A.M.I.C.E., on "The Design and Construction of the Spelga Dam."

Tuesday, 2nd February, 1960

Mr. R. Boorman, F.R.Ae.S., on "Aircraft Structures."

Tuesday, 1st March, 1960

Annual Function.

Meetings will be held in the Civil Engineering Department of the Queen's University of Belfast at 6.30 p.m., unless otherwise notified, and will be preceded by tea at 5.45 p.m.

Hon. Secretary: L. Clements, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., 3, Kingswood Park, Cherryvalley, Belfast.

SCOTTISH BRANCH

The following meetings have been arranged:

Tuesday, 19th January, 1960

Mr. W. Underwood, F.R.I.B.A., on "The Relationship between Architect and Structural Engineer."

Friday, 19th February, 1960

Combined Meeting with the West of Scotland Branch of The Institution of Civil Engineers.

Mr. N. M. Brydon, M.B.E., B.Sc., M.I.Struct.E., M.I.C.E., on "Concrete."

Tuesday, 15th March, 1960

Mr. W. G. N. Geddes, B.Sc., M.I.Struct.E., M.I.C.E., on "Piling in Structural Engineering."

The above meetings will be held at The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, commencing 7 p.m.

Hon. Secretary: W. Shearer Smith, M.I.Struct.E., A.M.I.C.E., c/o The Royal College of Science and Technology, George Street, Glasgow, C.1.

SOUTH WESTERN SECTION

The following meetings have been arranged:

Friday, 12th February, 1960

In Torquay. Mr. M. R. Hawkins, A.M.I.Struct.E., on "The Structural Engineer in Municipal Engineering."

Venue and time of meeting to be announced later.

Friday, 11th March, 1960

In Plymouth. Mr. J. D. Norfolk, M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., on "The New Queen Elizabeth Dock at Falmouth."

At the Duke of Cornwall Hotel, 6 p.m. Tea at 5.30 p.m.

Hon. Secretary: C. J. Woodrow, J.P., "Elstow," Hartley Park Villas, Mannamead, Plymouth, Devon.

WALES AND MONMOUTHSHIRE BRANCH

The following meetings have been arranged :

Wednesday, 20th January, 1960

At Swansea. Joint Meeting with the South Wales Institute of Architects, to hear a lecture on "The Reconstruction of Swansea Market."

Thursday, 11th February, 1960

At Cardiff. Mr. E. W. H. Gifford, B.Sc., M.I.C.E., A.M.I.Struct.E., and Mr. H. E. Lewis, M.Sc., on "Some Long Span Prestressed Bridges."

Wednesday, 9th March, 1960

At Swansea. Junior Members' Evening. Papers will be given by Graduates and Students.

Meetings at Cardiff will be held at the South Wales Institute of Engineers, Park Place, and in Swansea at the Mackworth Hotel, High Street, commencing 6.30 p.m.

Hon. Secretary : K. J. Stewart, M.I.Struct.E., A.M.I.C.E., 15, Glanmor Road, Swansea.

WESTERN COUNTIES BRANCH

The following meetings have been arranged :

Friday, 8th January, 1960

Mr. C. E. Saunders, M.I.Struct.E., on "Practical Applications of the Engineers' Training."

Friday, 5th February, 1960

Joint Meeting with the Bristol and Somerset Society of Architects.

Forum—J. T. Redpath, M.B.E., A.R.I.B.A., Architect.
C. D. Browning, A.R.I.C.S., Quantity Surveyor.
F. V. Allen, Contractor.
J. B. Bennett, M.I.C.E., M.I.Mun.E., Engineer.
Question Master, The Chairman.

Tuesday, 16th February, 1960

Annual Dinner and Dance.

At the Ashton Court Country Club, Bristol, from 7.30 p.m. to 1 a.m.

Friday, 4th March, 1960

Combined Meeting with the Institution of Civil Engineers.

Mr. H. G. Cousins, B.Sc., M.I.Struct.E., M.I.C.E., on "Concrete Structures."

Meetings will be held in the Small Lecture Theatre, University Engineering Laboratories, University Walk, Bristol 8, commencing 6 p.m., preceded by tea at 5.30 p.m.

Hon. Secretary : A. C. Hughes, M.Eng., A.M.I.Struct.E., A.M.I.C.E., 21, Great Brockeridge, Bristol 9.

YORKSHIRE BRANCH

The following meetings have been arranged :

Wednesday, 13th January, 1960

At Sheffield. Mr. R. M. Finch, O.B.E., M.I.C.E., City Engineer, Nottingham, and Mr. A. Goldstein, B.Sc.(Eng.), A.M.I.Struct.E., A.M.I.C.E., on "The Clifton Bridge, Nottingham."

Wednesday, 20th January, 1960

At Leeds. Mr. O. A. Kerensky, B.Sc., M.I.Struct.E., M.I.C.E., on "Modern Large Span Suspension Bridges."

Wednesday, 17th February, 1960

At Leeds. Mr. E. Longbottom, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "The Future of Military Bridge Design."

Wednesday, 2nd March, 1960

At Scunthorpe. Joint Meeting with the East Midlands Association of the Institution of Civil Engineers.

Dr. K. C. Rockey, A.M.I.C.E., A.M.I.Mech.E., on "Web Buckling and the Design of Web Plates."

At the Blue Hotel, 6.30 p.m.

Wednesday, 16th March, 1960

At Leeds. Joint Meeting with the Yorkshire Association of The Institution of Civil Engineers and the Yorkshire and Lincolnshire Branch of the Institution of Highway Engineers.

Mr. J. M. Fisher, B.Sc., M.I.C.E., Dr. A. R. Lee, A.I.C.E., and Dr. R. S. Millard, M.I.C.E., on "Research and its Application to Road Construction."

Wednesday, 23rd March, 1960

At Hull. Joint Meeting with the Hull and East Riding Branch of the Institution of Civil Engineers.

Mr. F. R. Bullen, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., (Vice-President) on "The Bearing Capacity of Driven Piles."

In the Lecture Theatre, Electricity Building, Ferensway, 6.15 p.m.

Meetings in Leeds will be held at the Metropole Hotel, King Street, and in Sheffield at the Royal Victoria Hotel. Meetings will commence at 6.30 p.m., preceded by buffet tea at 6.15 p.m.

Hon. Secretary : W. B. Stock, A.M.I.Struct.E., 34, Hobart Road, Dewsbury, Yorks.

UNION OF SOUTH AFRICA BRANCH

Hon. Secretary : A. E. Tait, B.Sc., A.M.I.Struct.E., A.M.I.C.E., P.O. Box 3306, Johannesburg, South Africa.

During weekdays Mr. Tait can be contacted in the City Engineer's Department, Town Hall, Johannesburg. Phone 34-1111, Ext. 257.

Natal Section Hon. Secretary : J. C. Panton, A.M.I.Struct.E., A.M.I.C.E., c/o Dorman Long (Africa) Ltd., P.O. Box 932, Durban.

Cape Section Hon. Secretary : R. F. Norris, A.M.I.Struct.E., African Guarantee Building, 8, St. George's Street, Cape Town.

EAST AFRICAN SECTION

Chairman : R. A. Sutcliffe, M.I.Struct.E.

Hon. Secretary : K. C. Davey, A.M.I.Struct.E., P.O. Box 30079, Nairobi, Kenya.

SINGAPORE AND FEDERATION OF MALAYA SECTION

Chairman : Mr. T. F. Lee, B.Sc.

Hon. Secretary : Mr. W. N. Cursiter, B.Sc., A.M.I.Struct.E., A.M.I.C.E., c/o Redpath Brown & Co. Ltd., P.O. Box 648, Singapore.

OFFICIAL APPOINTMENTS

NEW ZEALAND MINISTRY OF WORKS
ENGINEERING STAFF

The New Zealand Ministry of Works invites applications for the following vacancies on the Permanent Staff. Positions, qualifications desired and salaries offered are as follows.

Vacancy No. 1. CIVIL ENGINEERS. Corporate Membership of the Institution of Civil Engineers, London, together with sufficient appropriate experience.

Commencing salaries up to £1,525 p.a.

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Enquiries, mentioning this publication and stating the Vacancy Number and the position sought, should be addressed to the High Commissioner for New Zealand, 415 Strand, London, W.C.2. Full details of duties, experience required, general information on the conditions of employment in the New Zealand Public Service and application forms will then be supplied.

ROAD RESEARCH LABORATORY (D.S.I.R.) Harmondsworth, Middlesex, requires Civil Engineers, Materials (Research) Engineers, in Senior Scientific/Scientific Officer grades, to be based on Tropical Section of R.R.L. and available for secondment to overseas territories to study locally available road-making materials, and help in developing methods of road-making appropriate to local conditions. Preference given to engineers with some field experience. After a period of laboratory training they will be posted for tours in British overseas territories, returning to work in the Tropical Section of the Road Research Laboratory between tours. Quals. : 1st or 2nd Class Hons. degree. At least three years postgraduate experience for S.S.O. grades. Starting salaries within the range S.O. £655-£1,150—S.S.O. £1,233—£1,460. Normal prospects of promotion to Principal Scientific Officer in mid-thirties (range up to £2,120) with possibilities of higher posts. Five day week. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting E.347/9A. Closing date 15th January, 1960.

GOVERNMENT OF THE
FEDERATION OF RHODESIA AND NYASALAND

Vacancy : Assistant Structural Engineer, Ministry of Works.

Applicants must be Corporate Members of the Institution of Civil and/or Structural Engineers, or hold a degree in Engineering with a minimum, in the latter instance, of four years ' post-qualification experience.

Applicants must have a sound knowledge of reinforced concrete design and detailing ; some experience of steel structure is desirable.

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Application forms and further details from the Secretary (R), Rhodesia House, 429, Strand, London, W.C.2.

OFFICIAL APPOINTMENTS—continued

STRUCTURAL ENGINEERS

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Application form and particulars from Hubert Bennett, F.R.I.B.A., Architect to Council EK/112/59. County Hall, S.E.1. (2629).

SURREY COUNTY COUNCIL

Applications are invited for the appointment of ASSISTANT STRUCTURAL ENGINEER, GRADE IV, £1,065-£1,220 p. a. plus £30 p.a. London Allowance. Must be qualified Structural or Civil Engineer and have had experience in design and detailing of steelwork and/or reinforced concrete for medium to large scale contracts.

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Full details, present salary and three copy testimonials to County Architect, County Hall, Kingston as soon as possible.

SITUATIONS VACANT

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ASSISTANT Engineers and Draughtsmen required by Consultants for design and detailing of varied works including harbours, bridges and industrial structures. 5-day week, modern offices. Salaries up to £800 according to experience. Apply giving usual details to Wilton & Bell, Roman House, Cripplegate Buildings, London Wall, E.C.2.

BIRMINGHAM Consulting Engineers require qualified Assistants and Draughtsmen for work on commercial, industrial and municipal buildings in steel and concrete. Write to James-Carrington & Partners, 19, Masshouse Lane, Birmingham, 5.

CONSULTING Engineers have vacancies for Reinforced concrete detailers and designer/Detailers in newly opened offices at Wembley Park. Salaries according to experience. Apply to Bylander Waddell & Partners, 169, Wembley Park Drive, Wembley, Middlesex.

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DESIGNER Detailer for all types of reinforced concrete structures required by Consulting Engineer with small but expanding West End practice. Excellent prospects for man with initiative. Please state salary required. Write Box 9070, STRUCTURAL ENGINEER, 43a, Streatham Hill, R.W.2.

C. J. COOK & Co. (Engineers) Ltd., require five reinforced concrete Designer/Detailers for expanding design office. Not less than ten years experience. H.N.C. or similar level. Salaries £800-£1,200 p.a., according to experience and ability. Five day week. Luncheon vouchers. Superannuation scheme after twelve months' service. Application forms from 54, South Side, Clapham Common,S.W.4. (MACaulay 5522).

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A. GLOVER, B.Sc.Tech., A.M.I.Struct.E., eight years site and design office experience, will be interested to hear from consulting engineers requiring site representation on R. C. work in Bristol and the West. Box No. 9069, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

JENKINS & Potter have vacancies for senior and junior structural assistants, Degree or Higher National and some R. C. experience essential, but steelwork timber experience appreciated.

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REINFORCED concrete detailers, all grades, required for new office opening in Bournemouth; good conditions, five day week. Salaries according to capabilities. Interviews London and Bournemouth. Details with present salary to Box 9064, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

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SITUATIONS VACANT—continued

STRUCTURAL ENGINEER

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STRUCTURAL Designers and Draughtsmen with a minimum of two years experience after gaining Higher National or equivalent, required by Consulting Engineers, 5-day week, luncheon vouchers. Salary £700 to £1,000 depending on qualifications and experience. Apply in writing with full details to Andrews, Kent & Stone, 60, Wardour Street, London, W.1.

STRUCTURAL Engineering Designer required in London Office of Consulting Engineers. Should have a University Degree in Engineering or the Associate Membership of either the Institution of Civil or Structural Engineers and must have had at least one year's experience on the design of structural steelwork. Some experience on reinforced concrete design would also be an advantage. Salary according to experience. Five day week. Pension Scheme. Luncheon Vouchers. Apply stating age and experience to Box No. 9071, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

W. S. ATKINS & Partners have vacancies in London for Draughtsmen and Designer/Draughtsmen with experience of preparing drawings for structural steelwork to H.N.C. standard for both design and drawing of structural steelwork. Permanent positions with Pension scheme, L.V. etc. 5-day week. Applications in writing to Personnel Manager, 158, Victoria Street, S.W.1.

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